



Division of Agricultural Sciences

UNIVERSITY OF CALIFORNIA

**FARM MACHINERY: COSTS,
PERFORMANCE RATES,
AND COMBINATIONS**

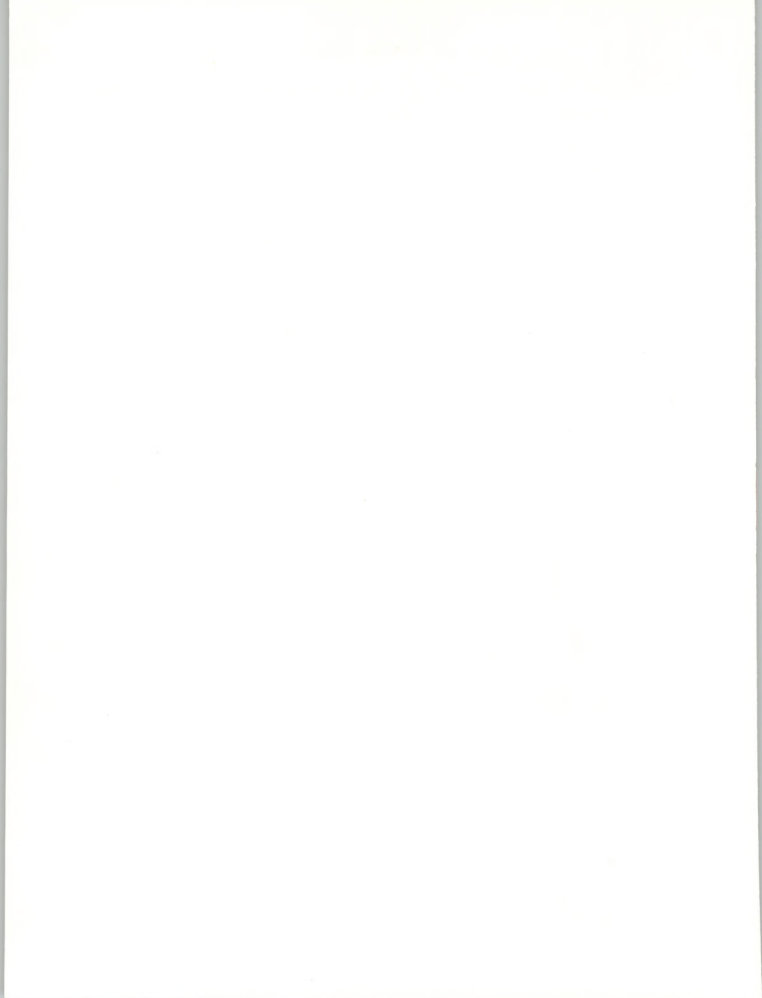
Southern San Joaquin Valley,
California

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**CALIFORNIA AGRICULTURAL EXPERIMENT STATION
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FOREWORD AND ACKNOWLEDGEMENTS

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FARM MACHINERY -- COSTS, PERFORMANCE RATES, AND COMBINATIONS --
SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA

by

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INTRODUCTION

This study was designed as an integral part of a study on economies associated with size of farm in the Southern San Joaquin Valley of California.^{3/} Previous studies of economies associated with farm size have indicated that a considerable portion of the change in average costs as farm size varies, can be attributed to changes in the use, type, or size of farm machinery.^{4/} Consequently, a thorough investigation into the machinery input was necessary to adequately investigate economies associated with size of farm. This report serves this purpose. In addition, this report presents basic data on machinery performance rates, costs, and combinations that are useful for making decisions not directly related to farm size. The number and type of machines covered in this report exceeds those required for the economies of size study.

Most of the recent machinery cost studies have originated in the Midwest. In examining these studies for their applicability for California conditions, it is found that the data are not suitable or available for many of the major pieces of farm machinery used in California. Important differences in machinery costs for cash field crop farms in California relative to many other areas are in large part due to (1) the importance of the crawler tractor, (2) the longer operating season and the related increase in annual use of machinery, and (3) higher performance rates for machinery due to large, level, and regularly shaped fields.

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^{3/} Paris, J. Edwin, and David L. Armstrong, Economies Associated with Size, Kern County Cash-Crop Farms, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation Research Report No. 269, December 1963.

^{4/} For example see, Dean, G. W., and H. O. Carter, Cost-Size Relationships for Cash-Crop Farms in Yolo County, California, Berkeley: University of California, Agricultural Experiment Station, Mimeographed Report No. 238, December 1960.

Investment in farm machinery has become increasingly important in relation to other farm capital items in recent years. In 1940, the investment in machines and motor vehicles on farms was \$3.1 billion or approximately six percent of the total value of physical farm assets. In 1958, it was \$17.6 billion, or more than ten percent of the total value of these assets.^{1/} Indications are that this trend will continue, perhaps not as the same rate but certainly in the same direction. Thus, the cost of owning and operating farm machines becomes increasingly important in the total farm picture.

OBJECTIVES OF THE REPORT

The purpose of this report is to (1) present a much needed report on machinery performance rates and cost under California conditions, (2) indicate the usefulness of the economic-engineering approach in obtaining reliable machinery data and cost, (3) determine least-cost machinery components for various farm sizes and cropping programs, and (4) compare the least-cost machinery investment and costs with those of actual farming operations of approximately the same size and cropping programs.

Although the data for this study are obtained in the Southern San Joaquin Valley, it is believed that much of the data will be useful as a guide in other parts of California and the West. An attempt is made to report the findings in such a manner that adjustments can be made with a minimum of effort.

PROCEDURE AND METHODOLOGY

The first step in the analysis is to obtain and specify the rates of accomplishment of farm machinery used on cash-crop farms. Some information on performance rates is available from current studies. However, much of the data on performance rates needs to be brought up to date. There are two major methods of obtaining primary data on performance rates. One method is that of obtaining estimates from farmer interviews. This method has several serious limitations. Foremost among these limitations is that the conditions are not fully specified under which the performance rates are estimated. Farmer bias is another limitation. Reliance is placed upon the farm operator's memory

^{1/} Parsons, Merton S., Frank H. Robinson, and Paul E. Strickler, Farm Machinery Use, Depreciation, and Replacement, U.S. Department of Agriculture, Agricultural Research Service, Statistical Bulletin No. 269, October 1960.

(although farm records are available in some instances) to provide the estimates of performance rates. The seriousness of the errors in performance rate estimates resulting from these limitations is unknown. However, these errors may be rather serious, especially when attempting to use these estimates to determine a least-cost machinery component.

The second method that can be used to obtain estimates of performance rates is the economic-engineering method or technique. This technique is essentially that of specifying each component part of an operation and the time and inputs required to perform the component parts of the operation. The time and inputs required are obtained from time studies, work samples, engineering estimates, and/or appropriate accounting data.^{1/} The component parts are then put together for each operation and the operations are in turn combined to form the requirements for producing the output.

Although the synthesis technique is old in the area of farm management, the use of the economic-engineering technique has been limited in this area. There are a few studies in which "engineering" techniques have been employed to collect labor and equipment performance rates.^{2/} This technique has also proven effective in assembling data in a number of economies of size studies involving fruit and vegetable packing plants.^{3/}

In this investigation heavy reliance is placed upon the economic-engineering technique to obtain and specify the machinery performance rates.

^{1/} For a more complete description of the sources of information see French, B. C., L. L. Sammet, and R. G. Bressler, "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," Hilgardia, Vol. 24, No. 19, University of California, Berkeley, July 1956.

^{2/} Engineering estimates as defined here fall into two categories. One type is that based upon horsepower, draft, etc. For examples of this type see Agricultural Engineers Yearbook, 1959 Edition, American Society of Agricultural Engineers, April 1959; or Promersberger, W. J., and G. L. Pratt, Power Requirements of Tillage Implements, North Dakota Agricultural Experiment Station Tech. Bul. 415, Fargo, June 1958. The second type of engineering estimates are those that might be classified as time studies where the actual operation is observed and timed. For example see, Ulvilden, James, Farm Labor Power and Machinery Performance for Selected Operations under Dryland and Irrigated Conditions in Central South Dakota, South Dakota Agricultural Economics, Pamphlet 43, College Station, revised August 1953. Also falling under this category is a study by Fellows, I. F., et al., Production Efficiency on New England Dairy Farms, 2. Economies of Scale in Dairying -- An Exploration in Farm Management Research Methodology, Connecticut Agricultural Experiment Station Bul. 285, Storrs, February 1952, Fellows, et al., developed standards of performance for dairy farm operations.

^{3/} Bressler, et al., op. cit.

Emphasis is also placed upon observing machinery performing the farm operations and recording, measuring, and timing each component part of the operations. This includes the speed of the machine, overlap of the implement, etc. These data are used to construct standards of performance by size and type of machine. Use of the economic-engineering technique does not guarantee that all of the limitations of the farmer-interview method are overcome. However, it appears to the authors that the economic-engineering technique has the advantages of not being based upon the farmer's memory and having the conditions, under which the performance rates are obtained, more fully specified.

The next step after determining the physical performance rates is the costing of each machine. Data necessary to cost the machinery were primarily obtained from accounting data and other secondary sources. However, some information was obtained from machinery-operator interviews. Costs per hour of operation are calculated for various hours of annual use of the machines.

The physical performance rates and the cost data are used to select least-cost machinery combinations. A least-cost machinery combination is defined in this report as the combination of machines that will perform all of the operations required for producing a specified quantity of a crop or combination of crops at the minimum cost subject to certain time restraints. Thus, the operations necessary to produce each crop and the time within the year that the operations must be performed to obtain the level of yields assumed in this report, are carefully specified. A different set of specified conditions might well result in a different least-cost machinery combination.

Least-cost machinery combinations are selected for six farm sizes and three cropping programs. These model farm units are based upon characteristics of farm units presently existing in Kern County.^{1/} Two least-cost machinery combinations are selected for each cropping program by farm size. One combination is selected under the condition of a constant product mix (the percent of each crop in a cropping program remains constant over all sizes of farms). The other least-cost combination is selected under the condition of a variable product mix (the percent that each crop, in a cropping program, is of the total acres of cropland varies as size of farm varies). The variable product mix is constructed to represent the product mixes presently found in Kern County by

^{1/} The selection of farm sizes and cropping programs are discussed in detail in Faris, J. E., and D. L. Armstrong, op. cit.

size of farm. Thus, the least-cost machinery combinations selected under the condition of a variable product mix indicate "what the farm operators can do" in the way of machinery selection to minimize costs. The variable product mix includes the effect of size of farm and changes in the product mix on machinery selection and cost minimization. In order to estimate the economies in machinery associated with farm size, it is necessary to delete the effect of changes in the product mix.^{1/} Consequently, the least-cost machinery combinations are selected under the conditions of a constant product mix. This will permit an estimate to be made of the technical economies associated with machinery. The linear programming technique is used to help select the 36 least-cost machinery combinations.

Data are available to construct the typical machinery combinations existing in 1961 on several sizes of farms in Kern County. These typical machinery combinations are compared with the least-cost machinery combinations selected under the condition of a variable product mix. These comparisons give an estimate of the differences between what the farm operators presently have in the way of machinery combinations and the least-cost combinations selected in this report.

The last step in the analysis is the presentation of the technical economies associated with machinery based on the constant product mix.

PERFORMANCE RATES

Time Studies

Heavy reliance was placed upon time studies in obtaining physical rates of performance. In driving through an area of Kern County the interviewers would look for a particular operation being performed. For purposes of illustration assume that additional information on the disking operation was needed. After locating this operation being performed, the interviewer measured the length of the field being disked. Usually the distance was one-fourth of a

^{1/} A discussion of this is presented in detail in Faris, J. E., and D. L. Armstrong, op. cit. A summary of the discussion is as follows: Farm size is defined in terms of acres. Consequently, cost (or investment) per acre is a logical and readily understood unit. However, economies associated with size are measured in terms of dollars per unit of output. Acres is an acceptable measure of output only when the output per acre remains constant over all farm sizes (under the conditions of a constant product mix). When output per acre changes as farm size changes (a variable product mix), then acres has little meaning as a measure of output for economies associated with machinery.

mile minus a roadway. The interviewer then noted the type and size of tractor and disk. A stop watch was used to determine the time required to disk one length of the field and the turn-around time. Work samples involving longer periods of time, e.g., several hours up to a full day, were made to verify rates of accomplishment, down time, etc. A number of "runs" were timed and recorded. In addition, the interviewer paced the tractor and disk with a stop watch in order to obtain a rough estimate of tractor speed.^{1/} The overlap of machinery used in such operations as disking was also recorded. The interviewer then talked to the machine operator to verify the size of the machinery and length of the field. Also the operator was questioned concerning fuel consumption, gear used, breakdown time, repairs of equipment, time required for lunch, getting to and from the field, lubrication of equipment, average daily accomplishment, etc. Some of this information was obtained to be used as a "check" on the economic-engineering data.

An attempt was made to take replications of the operations observed until the rates of performance fell into a consistent pattern.^{2/} This was accomplished for harvest operations and those operations where one or two tractor sizes are typically used to perform an operation. For example, a small wheel tractor is typically used for the cultivation operation.^{3/} Five or six observations for these types of operations were usually sufficient to obtain consistent performance rates.^{4/} For some operations, e.g., disking, a large number of tractor and implement size combinations are used.^{5/} It was not economically feasible to obtain a number of replications for each possible combination. However, several replications were obtained for the more common combinations of tractor and disk sizes. Although more than 25 observations were obtained for the disking operation, there are some tractor and disk size combinations for which no observations were obtained from the time studies. The observations obtained, although limited in number, serve as a basis for estimating physical input-output relationships among tractor sizes by size of implement.^{6/}

^{1/} The number of steps (three-foot) taken in 20 seconds divided by ten, approximates the speed in miles per hour.

^{2/} Consistency is a subjective term. The connotation of a consistent pattern as used here was when the observations of performance rates began to fall into a generally uniform pattern.

^{3/} A small tractor has 25-35 drawbar horsepower.

^{4/} More than five or six observations were usually obtained on any one operation. In addition, the implement might be of different sizes, e.g., a two-row, four-row, or six-row cultivator.

^{5/} Each tractor size might be associated with two or three sizes of implements.

^{6/} Regression analysis was used to estimate some of the relationships among tractor size and implement size.

The above observations were obtained in areas of predominately medium-textured soils. Consequently, it is assumed that the performance rates are based on and attainable in medium-textured soils. It is quite obvious that some of the observations were not on medium-textured soils as the sampling unit included other than medium-textured soils. The effect of this on the performance rates is unknown although the authors do not believe that it is very great. Most of the observations were obtained during the spring and summer months. During this period, the soil is relatively "dry" for the land preparation operations. The performance rates, for some of the tillage operations, may be somewhat higher than if the operations had been timed just after the fall and winter rains.

Additional Sources of Data

Other sources of information were used to supplement and check the data obtained from the time studies. Engineering information from equipment companies and their representatives, from manufacturers' specifications and the Nebraska tractor tests, and from several other empirical time studies were used. Estimates of performance rates from nonengineering empirical studies were consulted. Mr. Edward Libra, a farm advisor located at Madera, California, also obtained a considerable amount of information for this study from farm records.

Calculating Rates of Accomplishment

The next step in the analysis is to move from the physical performance rates to a measure of output per unit of time. This is necessary to permit cost rates to be applied. Thus, the performance rates, e.g., speed of a machine, overlap of an implement, etc., are to be expressed in terms of rates of accomplishment per hour or per day. These rates of output or accomplishment are calculated using equations that have been used by agricultural engineers for a number of years. The particular formulation used in this report is similar to that used by Burdick in a labor analysis study in Colorado.^{1/}

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^{1/} Burdick, R. T., A New Technique for Field Crop Labor Analysis, Colorado Agricultural Experiment Station, Tech. Bul. 36, June 1949.

Theoretical maximum.--The theoretical maximum rate of accomplishment is usually expressed as: $T = \frac{SW}{8.25}$.^{1/} This corresponds to a production function for which there are no delays of any nature associated with the machine operation. It is impossible to attain the theoretical maximum due to: (1) field operation delays such as turning at the end of the field and (2) nonfield operation delays, such as travel to and from the field. Consequently, the above formulation must be modified.

Field operation rates of accomplishment^{2/} .--The rate of accomplishment per hour under field operating conditions must take into account delays resulting from turnarounds, filling fertilizer or seed hoppers and spray tanks, emptying grain from harvesters, overlap of equipment, etc. To account for these delays the theoretical rates of accomplishment are modified and expressed as:

$$F = \left[\frac{S(W-O)}{8.25} \right] \left[\frac{t_e}{t_e + (t_h + t_a)} \right]$$

where: F = field operation rate of accomplishment of a machine in acres per hour,

W-O = effective width of the machine or implement in feet. This is the actual width of the implement minus overlap.

t_e = time per pass or round with no time loss,

t_h = time lost per pass or round due to turning,

t_a = time losses per pass or round due to adding seed or fertilizer, unloading harvester, unclogging machine, etc.

The field operation rates of accomplishment take into account delays resulting from minor adjustments of machinery. Delays resulting from a machine breaking down are not included in these rates of accomplishment.

The length of the field is important in determining the field operation rates of accomplishment. The rates of accomplishment presented in this report

^{1/} T = theoretical rate of coverage possible by machine expressed in acres per hour. It assumes no loss in time and maximum use of the full-rated machine width,

S = speed of machine in miles per hour,

W = actual rated width of implement in feet,

8.25 = a constant. A machine one-foot wide would travel 8.25 miles to cover one acre.

^{2/} The term used by many agricultural engineers to denote the rate of output in field operations is "field capacity."

are based on a field length of one-fourth mile as this is the most common length. Rates of accomplishment for machines operating in fields of one-half mile in length are as much as five percent greater. Field operation rates of accomplishment for machines commonly used on cash-crop farms in the Southern San Joaquin Valley are presented in Appendix Table 1 in the column titled "acres per hour."

Field and nonfield operation rates of accomplishments.--The field operation rates of accomplishment are based upon the time that machinery is in the field ready for operation. However, there are other losses in time that must be taken into account when calculating the number of acres that can be covered in a day by a machine. These nonfield operation delays include time lost going to and from fields, lunch time, lubrication time, time lost because of major breakdowns, time lost because trucks are not immediately available to haul harvested crops from the field, etc. Estimates of the time required in nonfield operations are necessary to determine the labor requirements associated with machinery operations. Some of the information necessary to make these estimates was obtained from the time studies but most of it was obtained from interviews with machine operators and field supervisors. Estimates based upon this information indicate that approximately two hours per day are required for nonfield operations.^{1/} Thus, in this report it is assumed that there is a two-hour loss each day in labor associated with machinery due to time losses other than those incurred in field operations. For example, if the workday is 12 hours, the field operations are performed 10 of the 12 hours. The field operation rate of accomplishment for a 14-foot self-propelled swather is 4.0 acres per hour (see Appendix Table 1). If the machine operator works a 12-hour day, the daily rate of accomplishment is 40 acres (10 x 4.0 rather than 12 x 4.0). The daily rate of accomplishment for a 10-hour workday using the swather is 32 acres.

^{1/} Approximately 20 to 30 minutes are lost going to and from the field and from other delays involved in starting and stopping a job. An additional 30 to 45 minutes of paid time are lost at lunch. If lunch breaks are not considered as paid time, then usually one-half hour is added to length of day, e.g., paid from 7 a.m. to 5 p.m. with one-half hour off for lunch with pay or paid from 7 a.m. to 5:30 p.m., one-half hour off for lunch without pay. Estimates obtained from tractor operators and field supervisors indicate that an average of 45 to 60 minutes per day is lost due to unexpected breakdowns, repairs, adjustments, etc.

COSTING PERFORMANCE DATA

A definite distinction between fixed costs and variable costs of operation is difficult to make and will not be strictly adhered to in this report. This is because some of the major categories of costs used in this report are composed of both the fixed and the variable elements, e.g., repair costs of certain machines.

Repair costs and depreciation costs receive special attention in the following discussion because of some of the complexities involved. The other machinery costs are specified with a minimum of discussion.

Repairs

There are several common ways to estimate total annual repair cost. The most common is to express total annual repairs as some percent of initial or new costs. This method assumes a relatively narrow range of annual usage within the area and is more appropriate in the Midwestern part of the United States. The operating season is shorter in this area compared to Western and Southern areas. Annual use for farm implements in the Midwest may not exceed 250 hours per year with tractors being used around 500 hours annually. Farmers in the western cotton areas used wheel tractors an average of 800 hours and crawler tractors 860 hours in 1955.^{1/} A number of tractors in the study area are used 1,500-2,000 hours per year. It is not expected that the repair costs are the same for tractors used 500 hours and 1,500 hours annually.

Richey^{2/} expressed repair cost of the entire life of the machine as a percent of new cost. The data from this study are often quoted in machinery cost studies throughout the country. Caterpillar Tractor Company, on the other hand, calculates repairs as 90 percent of the annual depreciation charge assuming the normal salvage value with straight-line depreciation. Estimates from these two sources do not appear to be applicable to California farm conditions.^{3/} Adequate information to determine repair costs is difficult

^{1/} Parsons, Merton S., et al., Farm Machinery: Use, Depreciation, and Replacement, Statistical Bul. No. 269, U.S. Department of Agriculture, Agricultural Research Service, October 1960.

^{2/} Richey, C. B., Cost Per Hour of Using Farm Machinery, Agricultural Extension Service, Ohio State University, Bul. 221, May 1943.

^{3/} Richey's estimates are based on a relatively small number of hours of annual use and Caterpillar's estimates are primarily based upon the operation of tracklayer tractors in construction work.

to obtain. Secondary sources^{1/}, records from a number of case study farms in the Southern San Joaquin Valley^{2/}, and information obtained from meetings with two groups of farm operators^{3/} are relied upon to serve as a basis for estimating repair costs.

An estimate of the relationship between repair costs and age, annual use, maintenance, etc., is not presently available from other sources. A comprehensive study of these relationships is beyond the scope of this investigation. Larson^{4/} analyzed data on tractor and other machinery repair costs from several different sources. The data from one source indicates that repair costs increase at an increasing rate with age while other sources of data indicate that annual repairs increase with age but the relationship is linear. To obtain additional information on this relationship the two groups of farm operators mentioned above were asked to indicate what they would expect concerning the relationship among annual use, age of machinery, and repair costs. Regressions were run on these estimates but the results were not satisfactory. It appears that the farm operators were unable to accurately estimate these relationships except for the narrow range of annual use that approximated their own operations. Consequently, the repair costs presented in this report do not take into account differences in repair costs by age of machine.

An analysis of the farm records and farm shop data indicates that annual repairs are a linear function of the hours of annual use. The estimates obtained from the two groups of farm operators substantiate this relationship.^{5/}

Using the information from the secondary sources, from the farm records of case study farms and the two groups of farm operators, a repair table was

1/ Much of the secondary information used was taken from Parsons, Merton S., et al., op. cit.; Richey, C. B., op. cit.; and Larson, G. H., G. E. Fairbanks, and F. C. Fenton, What It Costs to Use Farm Machinery, Bul. 417, Kansas State University, April 1960.

2/ Edward Libra, Farm Advisor in Madera County, California, obtained information from records of approximately 20 farm operations in the Southern San Joaquin Valley. This information was primarily obtained for this study.

3/ Two groups of eight farm operators in each group met with Mr. Libra and the authors in an attempt to estimate the relationships between hours of annual use and repair costs based upon their records and experience.

4/ Larson, George Herbert, Methods for Evaluating Important Factors Affecting Selection and Total Operating Costs of Farm Machinery, unpublished Ph.D. dissertation, Michigan State University, 1955.

5/ Based upon the repair costs of their present operations.

constructed (Appendix Table 2).^{1/} An hourly rate for repairs was estimated for each piece of machinery. This also includes the cost of maintenance such as grease and oil. These hourly repair rates are expected to be too high for new equipment and too low for old equipment in that they do not account for the expected increase in repair costs as a machine becomes older. For machinery pulled with a power unit, e.g., plows, disks, etc., the annual repair costs are obtained by multiplying the hours of use by the hourly repair costs. The annual repair costs for tractors, self-propelled harvesters, and certain other specialized machines are calculated by adding a fixed charge of two percent of new cost to the sum of the hourly repair costs. This coincides with much of the information available on repair costs. Annual repair and maintenance rates, by hours of annual use, are presented in Figures 1 and 2 for general categories of power machinery and implements.

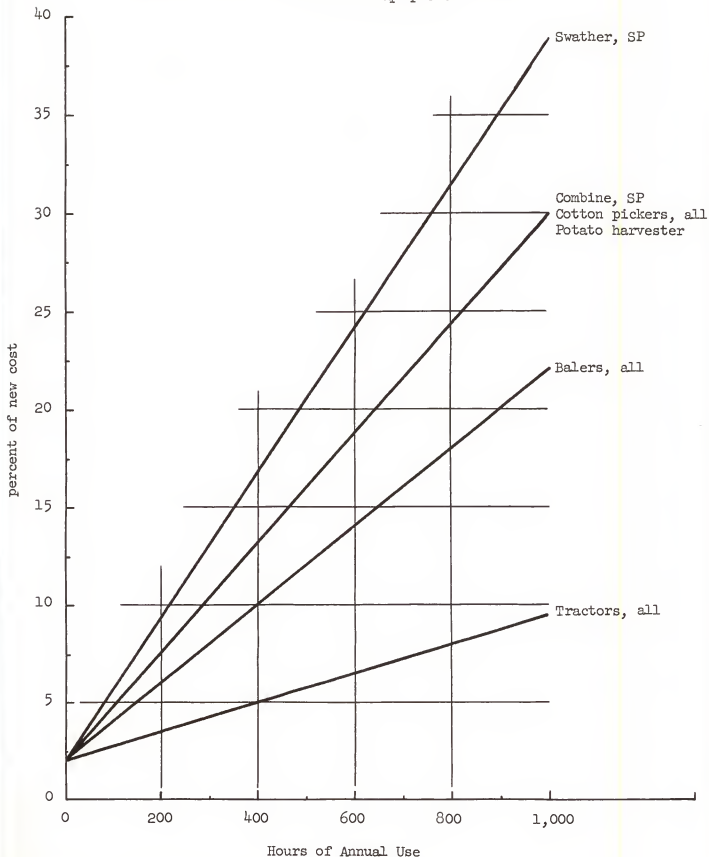
Depreciation

In order to obtain an estimate of the annual depreciation (decrease in value) of a machine, it is necessary to estimate the expected life of a machine. A national survey of farm machinery was made by the United States Department of Agriculture in 1956, indicating the relationship between hours of annual use and the life of a machine for a number of machines.^{2/} The relationships were presented by type of farms, e.g., cotton farms, and by geographic locations. The information in the report was used in this study as a base for estimating the relationships among annual use, obsolescence, and expected life of machinery. Information obtained from the two groups of farm operators in Madera County was used to supplement and verify data from the report. The effect of obsolescence is not explicitly noted. However, the expected length of life of the harvesting machines is affected by the obsolescence factor. Consequently, the assumed useful life of harvesting machines is less than it would have been had obsolescence not been a factor. The relationships between years of useful life and the total hours of use are presented in Table 1 for tractors, tillage machines, planting machines, and harvesting machines.

^{1/} Repair costs are for machinery maintained in a state of "good" repair. This is to avoid the extremes of "letting the machinery run down" or spending an amount in excess of that required to keep the equipment in good operating condition.

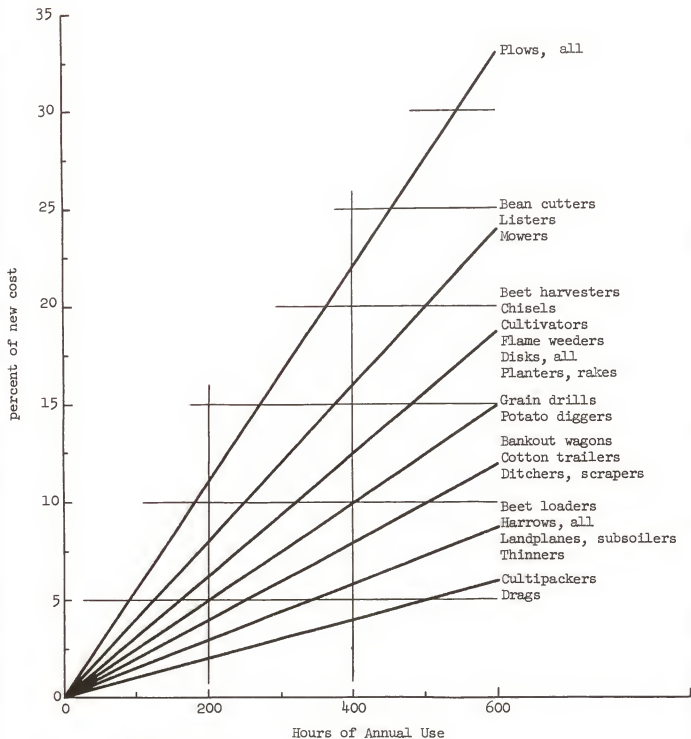
^{2/} Parsons, Merton S., et al., op. cit.

FIGURE 1. Repair and Maintenance Rates per Year
For Power Equipment



Source: Appendix Table 2.

FIGURE 2. Repair and Maintenance Rates per Year for Selected Farm Machinery Implements



Source: Appendix Table 2.

TABLE 1

Estimated Relationship Between Expected Life and Use
by Type of Machine

Hours per year	Tractors		Tillage machines		Planting machines		Harvesting machines	
	Life in							
	years ^{a/}	hours	years	hours	years	hours	years	hours
50					20	1,000		
100	20.0	2,000	15.0	1,500	12	1,200	12.0	1,200
150	16.7	2,500	13.3	2,000	10	1,500	12.0	1,800
200	15.0	3,000	12.0	2,400	8	1,600	11.0	2,200
250	14.0	3,500	10.5	2,600	7	1,750	10.0	2,500
300	14.0	4,200	9.0	2,700	6	1,800	9.0	2,700
400	12.5	5,000	7.0	2,800	5	2,000	7.0	2,800
500	12.0	6,000	6.0	3,000	4	2,000	6.0	3,000
600	12.0	7,200	6.0	3,600			5.0	3,000
800	11.0	8,800	5.0	4,000			4.0	3,200
1,000	10.0	10,000	4.0	4,000			4.0	4,000
1,400	7.0	10,500						
1,800	6.0	11,000						
2,200	5.0	11,500						

^{a/} Life in years approximates the season for replacement due to either obsolescence or wear. Normal life of tractors 10,000 hours; tillage machines 2,500 hours; planting machines 1,500 hours; harvesting machines 2,000 hours. Obsolescence is usually high for harvesting machines.

Source: From farm records in survey area.

Parsons, Merton S., et al., Farm Machinery: Use, Depreciation, and Replacement, Statistical Bulletin No. 269, U. S. Department of Agriculture, Agricultural Research Service, October 1960; and Richey, C. B., Cost Per Hour of Using Farm Machinery, Bulletin 221, Ohio State University, May 1943.

In determining the annual depreciation the delivered prices of new machinery for 1962 were used.^{1/} Depreciation is calculated on an hourly basis using the relationships presented in Table 1.^{2/} A ten percent salvage value is used for most pieces of machinery although no salvage value is assumed for several of the basic land preparation pieces of machinery.^{3/}

Interest, Taxes, and Housing

A ten percent charge per year, based on the average valuation of the machinery, is made for interest, taxes, and housing. Of this ten percent, six percent is the interest charge.

Fuel Storage

A small annual charge was included for fuel storage. An investment of \$50.00 per tractor is required.^{4/} The life of the storage tank is specified to be 15 years with an interest charge of six percent on one-half of the investment.

Fuel Costs

Fuel consumption is a function of the work being performed. The work performed was divided into two categories, heavy and light. Fuel consumption is calculated for heavy working conditions under the assumption that the tractor is performing at 75 percent of its maximum drawbar horsepower and for light working conditions under the assumption that a tractor is performing at 50 percent of its maximum drawbar horsepower.^{2/} The fuel consumption for self-propelled equipment is estimated using several engineering sources and the questionnaires obtained from machinery operators in Madera County. A price of \$.18 per gallon is used for gasoline and a price of \$.12 per gallon for diesel fuel.

^{1/} See Appendix Table 3 and Appendix Table 4.

^{2/} For example, a \$4,000 tractor used 800 hours per year would have an expected life of 8,800 hours. Cost minus salvage value equal \$3,600. The depreciation per hour is $\$3,600 \div 8,800 = \$.41$ per hour.

^{3/} When some of the low cost pieces of machinery is fully depreciated, it is either not traded in or the value of these machines is extremely low at that time.

^{4/} Estimated from cost records furnished by Mr. Edward Libra.

^{5/} The consumption rates are calculated from information obtained from current Nebraska tractor tests.

Labor Cost^{1/}

The labor costs are specified to be \$1.50 per hour for machine operators. This figure includes Social Security payments, Workmen's Compensation, and other perquisites. Labor not actually operating the machinery is costed at \$1.25 per hour.

Machinery Custom and Rental Rates

Many of the operations can be and are performed for the farm operator on a custom basis. Custom rates for some of the more common custom operations were obtained from a sample of farm operators in Kern County and are presented in Appendix Table 5.

Machinery can also be rented. Rental rates obtained from tractor and implement dealers in Kern County are presented in Appendix Table 6.

SELECTION OF LEAST-COST MACHINERY COMPONENTS

Least-cost machinery components will be selected for six sizes of farms ranging from 80 acres to 3,200 acres and for three basic cropping programs. The basic cropping programs are: (1) cotton-alfalfa, (2) cotton-alfalfa-potatoes, and (3) cotton-alfalfa-barley (dc)-milo (dc).^{2/} However, each basic cropping program is investigated under two sets of conditions. The first set specifies that the relative importance of each crop in the cropping program remains constant for all farm sizes. This is denoted as the constant product mix. The second set of programs specifies that the relative importance of certain crops increases (decreases) as farm size varies. This is denoted as the variable product mix.^{3/} The acres of each crop by product mixes and cropping programs are presented in Table 2. This results in a total of 36 different farm operations.

Based on the performance and cost data presented the least-cost equipment components for the various farming operations can be selected. This involves answering two basic questions. (1) For each size of tractor, what is

^{1/} Labor costs are based upon information obtained from unpublished data, Capital-Labor Study in Kern County, Department of Agricultural Economics, Davis.

^{2/} Double cropping of barley and milo will be denoted throughout the manuscript as barley (dc)-milo (dc).

^{3/} The explanation for selecting these product mixes and cropping programs is presented in Faris, J. E., and D. L. Armstrong, op. cit.

TABLE 2

Absolute and Relative Importance of Individual Crops Under Constant
and Variable Product Mixes for Three Cropping Programs a/

Crop	80 acre		160 acre		320 acre		640 acre		1,280 acre b/		3,200 acre	
	Crop acres	Percent of total	Crop acres	Percent of total	Crop acres	Percent of total	Crop acres	Percent of total	Crop acres	Percent of total	Crop acres	Percent of total
<u>Constant product mix</u>												
Crop program 1												
Cotton	30	37.5	60	37.5	120	37.5	240	37.5	480	37.5	1,200	37.5
Alfalfa	45	56.2	90	56.2	180	56.2	360	56.2	720	56.2	1,800	56.2
Crop program 2												
Cotton	30	37.5	60	37.5	120	37.5	240	37.5	480	37.5	1,200	37.5
Alfalfa	37	46.2	74	46.2	148	46.2	296	46.2	592	46.2	1,480	46.2
Potatoes	8	10.0	16	10.0	32	10.0	64	10.0	128	10.0	320	10.0
Crop program 3												
Cotton	30	37.5	60	37.5	120	37.5	240	37.5	480	37.5	1,200	37.5
Alfalfa	25	31.2	50	31.2	100	31.2	200	31.2	400	31.2	1,000	31.2
Barley (dc) }	20	25.0	40	25.0	80	25.0	160	25.0	320	25.0	800	25.0
Milo (dc) }												
<u>Variable product mix</u>												
Crop program 1												
Cotton	35	43.5	64	40.0	120	37.5	214	33.5	358	28.0	800	25.0
Alfalfa	40	50.2	86	57.7	180	56.2	366	60.2	642	65.7	2,200	68.7
Crop program 2												
Cotton	35	43.5	64	40.0	120	37.5	214	33.5	358	28.0	800	25.0
Alfalfa	40	50.2	66	41.2	140	43.7	306	47.7	682	53.2	1,800	56.2
Potatoes	0	0	20	12.5	40	12.5	80	12.5	160	12.5	400	12.5
Crop program 3												
Cotton	35	43.5	64	40.0	120	37.5	214	33.5	358	28.0	800	25.0
Alfalfa	23	28.7	46	28.7	96	30.0	211	33.0	455	35.5	1,212	37.9
Barley (dc) }	17	21.3	40	25.0	84	26.2	175	27.3	387	30.2	988	30.8
Milo (dc) }												

a/ Crop acres are assumed to be 93.75 percent of the total acres. Percentages are for percent of total acres and add up to approximately 93.75 percent.

b/ Cotton allotment constant from 1,280 acres at 25 percent.

Source: Paris, J. E., and D. L. Armstrong, *Economies Associated with Size, Kern County Cash-Crop Farms*, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation Research Report No. 269, December 1963.

the size of implement that will result in the lowest cost for performing each operation? For example, what is the least-cost size of disk or plow to use with a particular size tractor? (2) What is the least-cost machinery component for all operations?^{1/}

Before the second question can be answered, it is necessary to specify the operations required for the production of each crop. Yield expectations are associated with the level at which certain operations are performed. This includes land preparation, planting, cultivating, spraying, and harvesting as well as the quantity of inputs associated with these operations, such as fertilizer and water. The level of application and technology pertaining to non-machinery inputs are based on the recommendation of other disciplines. The level of crop yields are consistent with these recommendations and are specified to be constant for all farm sizes.

Matching Tractors and Implements

Implements can be grouped into two classes by the type of operations performed: (1) implements where the rates of accomplishment are affected by the power unit associated with the implement, and (2) implements where size, speed, and consequently, rate of accomplishment, is nearly constant regardless of the power unit used.

Operations Where Rate of Accomplishment is Affected by Size of the Power Unit

It is primarily in land preparation operations that the size of power unit affects the rates of accomplishment. This includes plowing, subsoiling, chiseling, disking, and landplaning. The disking operation will be used to illustrate the basic physical relationships and the selection of the least-cost, tractor-implement combination.

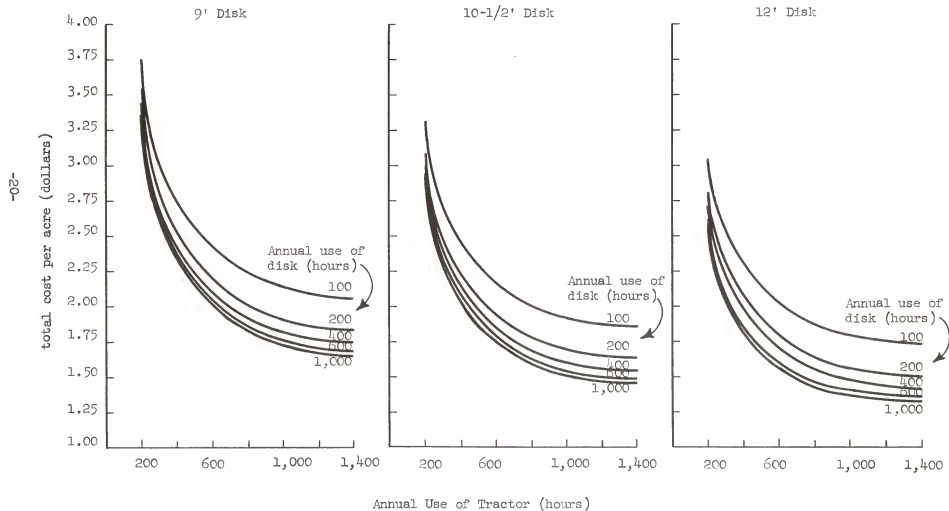
The costs per acre for disking with a C-55 tractor and three sizes of disks are presented in Figure 3.^{2/} The average total cost per acre decreases as the hours of annual use of the tractor and/or the disk increases.^{3/} For

^{1/} In a number of instances it might be that these two questions would have to be answered simultaneously. Fortunately, that is not necessary in this particular investigation.

^{2/} The C-55 tractor is a crawler or tracklayer tractor with 55 drawbar horsepower. The system for tractor size designation is described in more detail in a later section.

^{3/} All tractor implement and labor costs associated with disking are included.

Figure 3. Total Disking Cost per Acre With C-55 Tractor and Three Disk Sizes
by Annual Use of Tractor and Disk



a specified number of hours of annual use for the disk and the C-55 tractor, the least-cost size of disk is the 12-foot disk. However, direct comparison of hours used for the disk and tractor would be misleading. A smaller disk would require more hours to cover the same acreage. Consequently, it is necessary to compare the cost of disking a specified acreage taking into account the differences in disking time for the three sizes of disks pulled by the C-55 tractor. This comparison is presented in Table 3. The cost per acre is always lower using the largest disk than when using the smaller disks. Although the C-55 tractor can actually pull a larger disk under some conditions, a 12-foot disk is the largest size disk that would normally be expected to be associated with a tractor of this horsepower.

The above comparisons indicate that the largest size implement normally associated with any power unit is the least-cost implement to use under the specified soil conditions.^{1/} Table 3 also indicates that the costing of the disking operation is dependent upon the total hours of annual use of the tractor. As the acres of disking increase the tractor is used closer to its capacity and the effect on costs of using the tractor for other operations becomes less.

Another analysis of the least-cost size of machinery (the figures are not presented) also indicated that when the hours of annual usage were low with respect to a tractor or disk that a lower cost per acre would be obtained by shifting to the next smaller size tractor and its related implements rather than shift to a smaller disk using the same tractor size.

The analyses indicate that the least-cost disk, where rate of accomplishment is associated with size of power unit, is the largest disk normally associated with the specified size of power unit or tractor. A similar analyses using other land preparation machinery indicate the same results as those obtained for the disking operation.^{2/} The selection of a machine depends primarily on the relationship between fixed costs and rate of accomplishment. As size of machine increases for a given acreage, (1) implement overhead cost per acre increases, (2) operating cost per acre for tractor and implements remains

^{1/} The observations on which the analysis is made are for machines operating in medium-textured soils and relatively dry soil. This statement might not be correct for machines operating under conditions of wet soils or heavy- (light) textured soils.

^{2/} The largest size implement normally associated with each size of tractor was determined by consultation with representatives of machinery manufacturers and by examining data obtained for determining the performance rates.

TABLE 3

Disking Cost per Acre for a C-55 Tractor Pulling Three
Sizes of Disks by Varying Hours of Annual Use

Acres to be disked and size of disk	Hours required for diskings a/	Total cost per acre, when in addition to diskings time, the tractor is used		
		100 hours	400 hours	600 hours
		dollars		
500 acres disked				
9' disk	192	2.96	2.53	2.30
10-1/2' disk	161	3.04	2.33	2.11
12' disk	143	2.90	2.09	2.03
1,000 acres disked				
9' disk	384	2.65	2.20	2.09
10-1/2' disk	322	2.46	2.01	1.88
12' disk	286	2.32	1.86	1.75
1,500 acres disked				
9' disk	577	2.27	2.05	1.98
10-1/2' disk	484	2.11	1.85	1.79
12' disk	428	2.01	1.73	1.66
2,000 acres disked				
9' disk	769	2.07	1.97	1.92
10-1/2' disk	645	1.89	1.76	1.70
12' disk	571	1.79	1.58	1.59
2,500 acres disked				
9' disk	962	1.98	1.90	1.86
10-1/2' disk	831	1.75	1.68	1.66
12' disk	714	1.73	1.61	1.58
3,000 acres disked				
9' disk	1,154	1.93	1.86	1.85
10-1/2' disk	968	1.71	1.65	1.61
12' disk	857	1.64	1.57	1.54

a/ The rates of accomplishment for diskings are: 9' disk -- 2.6 acres per hour, 10-1/2' disk -- 3.1 acres per hour, 12' disk -- 3.5 acres per hour. The costs and rates of accomplishment are based on an offset disk-harrow.

Source: Figure 5 and Appendix Table 1.

fairly constant, and (3) operator and associated labor costs per acre decreases due to increased rate of accomplishment.

In comparing operations such as disking, the larger disks result in the lowest cost primarily because labor cost per acre decreases faster than overhead cost per acre increases. This same relationship exists for other pieces of basic land preparation equipment, with the exception of the more expensive pieces of land preparation equipment, used a small number of hours annually. In such a case, however, custom charges are probably lower than the cost of owning and operating of this machinery.^{1/}

The remainder of the analysis will be based upon the assumption that the least-cost, implement-tractor combinations are obtained by using the largest implement normally associated with each size of tractor.^{2/}

Operations Where the Size of Implement Is Not Determined by Size of Power Unit

The sizes of a number of implements are primarily selected on criteria other than size of the power unit. Implements such as planters and cultivators are selected on the basis of the number of rows that they cover at one time. These implements are usually two-row, four-row, or six-row implements.^{3/} Once the size of the planter has been determined (in terms of the number of rows) the size of a number of other implements has also been determined, e.g., the size of the cultivator.

Four-row implements have been selected for this analysis in that most of the row implements used in Kern County at the present time are four-row implements. Sufficient information is not available to evaluate other sizes.^{4/} Presently, a number of variations in row spacing of cotton are being attempted such as two rows of cotton and two rows not planted. Yields of cotton may increase sufficiently to make this type of planting more profitable than solid plantings of cotton. However, for this study a solid planting of cotton is

^{1/} An analysis of these relationships were made for several of the land preparation implements which substantiated this statement.

^{2/} As not all possible comparisons were made, there may be some exceptions to this assumption.

^{3/} There are other sizes but they are not common at the present time and have usually been specially constructed for or by the farm operator.

^{4/} Six-row or even eight-row implements would be expected to result in lower per acre costs in many instances. Undoubtedly, sets of these larger implements will appear more often in the future on the larger size farms.

specified and four-row equipment is assumed to be used on these plantings as well as on the other crops. The size of a number of implements classified as miscellaneous light draft implements is not determined per se by the size of the power unit. Harrows, for example, require relatively little power to pull and their sizes are determined more by the size of the disk or companion implements than by the power of the tractor. Cultipackers and ditchers are examples of other implements where power is of small consequence in the selection of these implements. The size of implement selected is based on the above criteria most appropriate for the implement under consideration.

Harvesting equipment is selected on the basis of time available for the harvesting operation, performance rates, and costs. Although the annual use levels may appear low in relation to time available, several other factors must be taken into account.^{1/} These are: (1) coordination with other operations, e.g., processing, marketing, hauling, etc.; (2) special harvesting conditions required because of moisture or temperature conditions; and (3) overcapacity to compensate for the probability of breakdowns.

Assumptions and Techniques Used in Determining the Least-Cost Machinery Combinations

The least-cost machinery combination as defined in this report is that combination of machines which will perform the operations required to produce specified outputs at the lowest cost (under the conditions specified). The least-cost combinations calculated are the least cost for a set of conditions with respect to (1) the machines being considered, (2) the operations performed, and (3) the time limit within which each operation must be performed.^{2/} A different set of conditions or assumptions might well result in a different least-cost machinery combination.

Types and Sizes of Machines Considered

Five sizes of wheel tractors are considered as possible sources of power. The sizes considered are W-25, W-35, W-45, W-55, and W-70 where the "W" stands

^{1/} This aspect of the analysis will be examined in the following section.

^{2/} It is assumed that all operations must be performed in a given time period. It is possible that in certain situations that net revenue could be increased by not performing all operations within the specified time limit. For example, the reduction in total revenue resulting from delayed planting of a crop might be more than offset by a decrease in machinery costs. This does not appear to be likely in most instances. Consequently, this possibility was not investigated.

for wheel tractor and the number represents the maximum drawbar horsepower of the tractor. Three sizes of crawler or tracklayer tractors are considered as possible sources of power. These are C-55, C-80, and C-120 where "C" stands for crawler and the number, the maximum drawbar horsepower rating. The W-25 tractor can be used for only the operations requiring a minimum of horsepower such as mowing, raking, planting, and cultivating. The W-35 and W-45 tractors can perform all of these operations plus pull a baler and perform relatively light land preparation operations such as disking. The W-55 and W-70 furnish sufficient power to perform all of the operations required to produce the crops. The C-55, C-80, and C-120 are used primarily for the land preparation operations. In addition to these eight tractors sizes and the related implements, some self-propelled machinery is also considered. This includes the self-propelled hay baler, hay swather, grain combine, and cotton picker. The potato digger and the potato harvester are both considered.^{1/} Whenever appropriate both one-row and two-row machines are included as possible choices.

In addition to the farm operator owning all of the equipment, the possibility of having some, although not all, of the operations performed on a custom basis is considered. A farming operation must have at least the equivalent of a 35-horsepower tractor. Renting of machinery is also excluded as a possibility in the following analysis.

Time Limitations and Types of Operations

In order to make the analysis more manageable, the operations were grouped by two criteria: (1) those operations requiring approximately the same size of power unit, and (2) those operations performed approximately at the same times within the year. Inspection of these groupings indicated that there are five major groupings with respect to the type and size of the power units that could be used. It also appears logical to divide the year into three major time periods.^{2/}

^{1/} Potatoes can be harvested using a one- or two-row digger with the potatoes picked up and sacked by hand. The other method considered was that of using the two-row potato harvester where much of the hand labor is eliminated.

^{2/} Several different time period groupings were investigated. Dividing the year into five time periods was investigated rather thoroughly. However, the added preciseness resulting from using five time periods rather than three time periods appears dubious.

The five major groups or categories of operations used in the analyses are: (1) light land preparation, (2) heavy land preparation, (3) miscellaneous light operations, (4) cultivation, and (5) harvest operations.^{1/} The three time periods used are: (1) T_1 , December 1 to March 15; (2) T_2 , March 16 to September 30; and (3) T_3 , October 1 to November 30. The operations to be performed by time periods are presented in Figure 4. The times that each of the major categories of operations must be performed within the year and the time period performed are presented in Table 4 for each of the crops considered in this study. For example, each acre of cotton must be "gone over" four times in the light land preparation operation in time period T_1 .

A composite rate of accomplishment is calculated for light land preparation (LLP), heavy land preparation (HLP), and (3) miscellaneous light operations (MLT) by size of tractor.^{2/} These composite rates of accomplishment, in terms of acres per hour, are obtained by dividing the total number of hours required per acre for each major category of operations by the number of times that the acre was "gone over." The composite rates of accomplishment by tractor size are presented in Table 5.

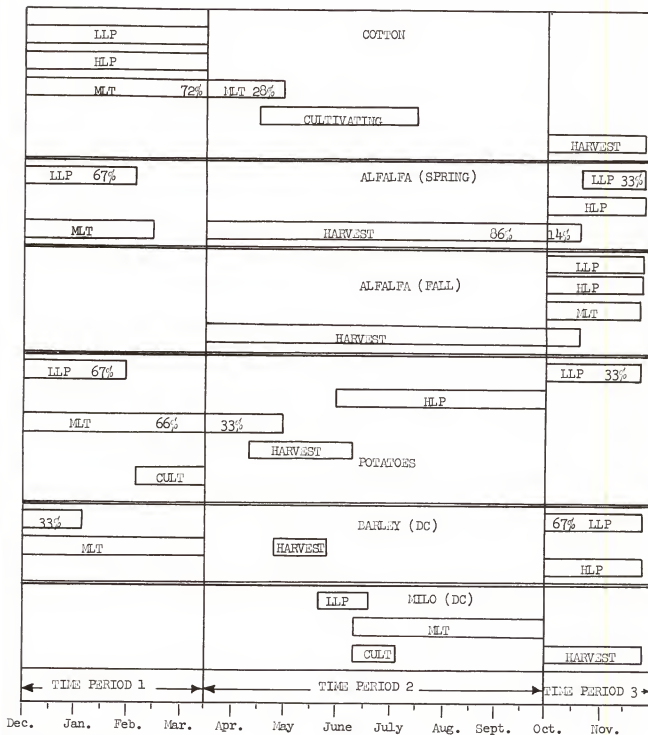
Costs were calculated for each tractor size and a selected number of implements. The cost per hour for the various sizes of tractors is presented in Figure 5. The tractor costs include all costs related to the tractors plus a \$1.50 labor charge for the driver. Implement costs are presented for light land preparation, heavy land preparation, miscellaneous light draft operations, and cultivation (Figures 6a-6d). To obtain the total cost of operation, the tractor and implement must be added. The two costs combined include the labor cost needed to complete the operation. For example, cotton planting requires two men, one man on the tractor and one to assist on the planter. The operator labor for the tractor is included in tractor cost and the added labor for assisting in the operation is included in the implement cost.

To obtain the cost per acre for the above operations, the total hourly cost (tractor and implement) is divided by the hourly rate of accomplishment (see Table 5).

^{1/} The individual operations included in each of these major categories are listed in Table 4.

^{2/} There are minor differences among crops in the operations performed within these major categories. However, the composite rate of accomplishment was very similar for all crops with respect to each of the three categories. Consequently, no distinction between rates of accomplishment was made among crops.

FIGURE 4. Time Limitations in Which Certain Operations Must be Performed for Each Major Field Crop



Source: Table 4.

TABLE 4

Acres of Operations Required for Each Acre of the Selected Crops

Crop	Light land preparation ^{a/}			Heavy land preparation ^{b/}			Misc. light operations ^{c/}			Cultivation	Harvest	
	T ₁ ^{d/}	T ₂	T ₃	T ₁	T ₂	T ₃	T ₁	T ₂	T ₃			
	acres ^{a/}											
Cotton	4.0			.67			5.0	2.0		6.0	2.0	
Alfalfa (fall) ^{e/}			1.5			.75			.67		7.0	
Alfalfa (spring) ^{e/}	1.0		.5			.75	.67				7.0	
Barley (dc)	.66		1.34			.33	3.0				1.0	
Milo (dc)		3.0						3.0		2.0	1.0	
Potatoes	3.0		1.0		.67		2.5	1.5		2.0	1.0	

a/ Light land preparation includes light draft land preparation equipment, e.g., plowing, disking, and shallow chiseling. These operations can be performed by larger wheel tractors and crawlers.

b/ Heavy land preparation includes heavy draft operations, e.g., subsoiling and land-planing.

c/ Miscellaneous light operations are light draft operations. Power requirement is not a limiting factor. Most operations are normally performed with wheel tractors, e.g., cultipacking, harrowing, planting, etc.

d/ The year is divided into three time periods; T₁, December 1 to March 15; T₂, March 15 to September 30; T₃, October 1 to December 1. Time periods 1 and 3 are the most limiting and most of the land preparation is accomplished in these two periods.

e/ The requirements for alfalfa are for the total acreage in the cropping program based on a three-year stand.

TABLE 5

Rates of Accomplishment per Hour and per Day by
Length of Day for Selected Operations

Operations ^{a/}	Rates of accomplishment for:		
	Field operations only ^{b/}	Field and nonfield operations ^{c/}	
	acres per hour	10-hour day	12-hour day
		acres per day	
Pick cotton, 1 row, mounted	.7	5.6	7.0
Pick cotton, 2 row, SP	1.5	12.0	15.0
Combine, 14', SP	2.8	22.4	28.0
Dig potatoes, 2 row	1.0	8.0	10.0
Potato harvester, pull 2 row	1.2	9.6	12.0
Light land preparation using:			
W-35 tractor	1.0	8.9	10.0
W-45 tractor	1.3	10.4	13.0
W-55 tractor	1.6	12.8	16.0
W-70 tractor	1.9	15.2	19.0
C-55 tractor	2.5	20.9	25.0
C-80 tractor	3.3	26.4	33.0
C-120 tractor	4.2	33.6	42.0
C-180 tractor	4.9	39.2	49.0
Heavy land preparation using:			
W-55 tractor	.9	7.2	9.0
W-70 tractor	1.2	9.6	12.0
C-55 tractor	1.6	12.8	16.0
C-80 tractor	2.1	16.8	21.0
C-120 tractor	2.8	22.4	28.0
C-180 tractor	3.2	25.6	32.0
Bale, pull (3 wire) ^{d/}	8.0 tons	48.0 tons	64.0 tons
Bale, SP (3 wire) ^{d/}	9.0 tons	54.0 tons	72.0 tons
Swather, 14', SP	4.0	32.0	40.0
Mower, 7'	3.2	25.6	32.0
Rake (side), 8'	3.8	30.4	38.0
Cultivate, 4 row	5.2	41.6	52.0
Misc. light operations	4.4	35.2	44.0

^{a/} Some of the operations are combined into one major operation, e.g., light land preparation.

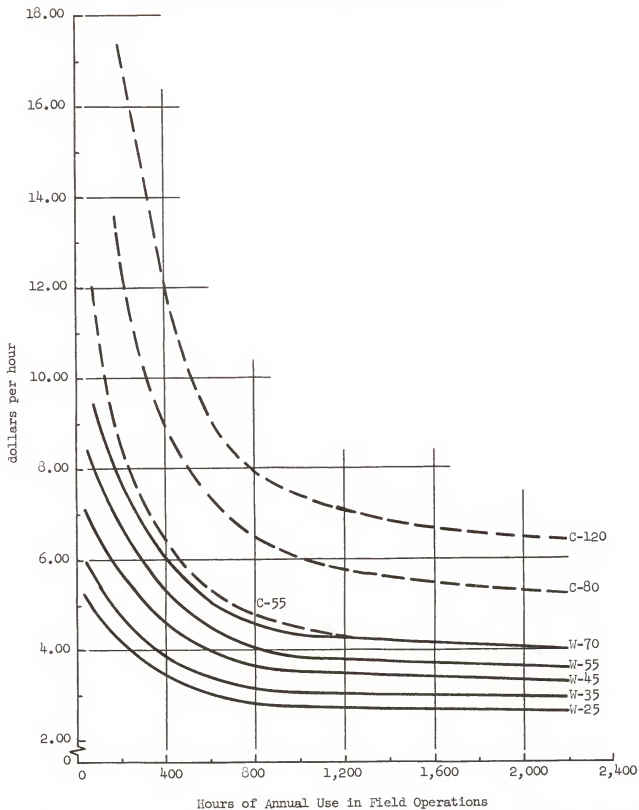
^{b/} Based upon the time that the machinery is in the field ready to perform the operation.

^{c/} Includes nonfield operations of 2 hours per day. The daily rates of accomplishment are obtained by subtracting 2 hours from number of hours in the work day and multiplying this figure by the hourly rates of accomplishment for field operations only.

^{d/} Use of balers is normally limited to periods during the night and early morning when there is sufficient atmospheric moisture to minimize shattering. This may be as low as 5-8 hours per day.

Source: Appendix Table 1.

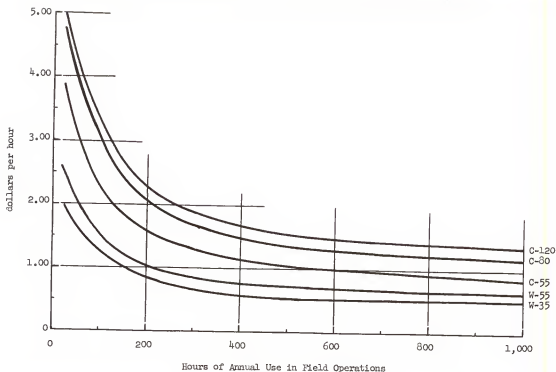
FIGURE 5. Tractor and Operator Cost per Hour^{a/}



^{a/} "W", wheel; "C", crawler, number denotes maximum dbhp. Labor cost of \$1.50 per hour is included in these costs.

Source: Appendix Table 3.

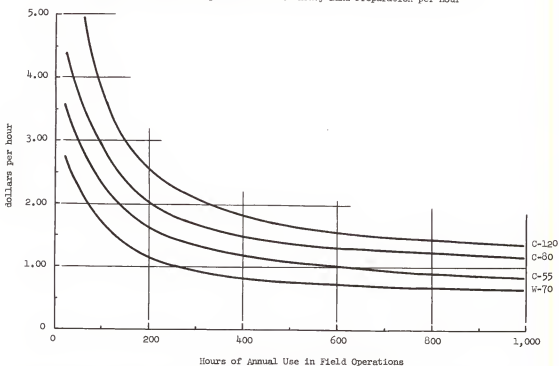
FIGURE 6a. Composite Implement Costs of Light Land Preparation per Hour^{a/}



^{a/} Includes disking, chiseling, and plowing. These are total implement costs per hour and do not include the cost of the tractor or the operator. Not all tractor sizes are included.

Source: Table 5 and Appendix Table 1.

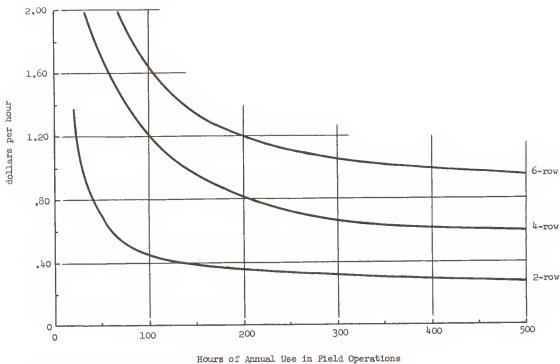
FIGURE 6b. Composite Implement Costs of Heavy Land Preparation per Hour^{a/}



^{a/} Includes subsoiling and landplaning. These are total implement costs per hour and do not include the cost of the tractor or the operator.

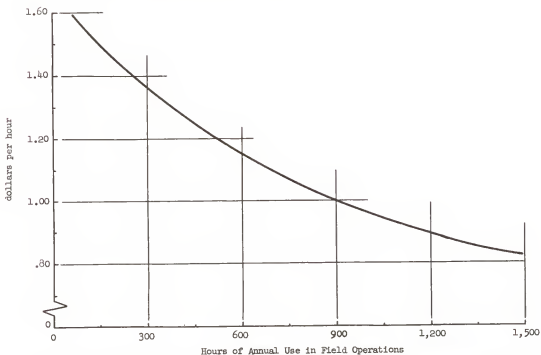
Source: Table 5 and Appendix Table 1.

FIGURE 6c. Cultivator Costs per Hour^{a/}



^{a/} The cost of the tractor and operator is not included.
Source: Table 5 and Appendix Table 1.

FIGURE 6d. Composite Implement Costs per Hour For Light Draft Operations^{a/}



^{a/} Includes furrowing out, making borders, broadcasting, harrowing, planting, and cultipacking. The cost of the tractor and tractor driver is not included. The cost of labor, in addition to the driver, for the planting operation is included at \$1.25 per hour.

Source: Table 5 and Appendix Table 1.

Cost curves are also presented for some of the major harvesting operations. Comparisons are made among per acre harvest costs using self-propelled machines, tractor pulled machines, and custom operations (see Figures 7a-7e). All machine costs and labor costs associated with the operation of the machine are included. As a tractor can, and probably would, be used for more than just the harvest operation, it is necessary to arbitrarily select some cost figure for tractors. A charge of \$3.50 per hour for a tractor and operator is used for the wheel tractor and a charge of \$4.75 is used for the crawler tractor.^{1/} Adjustments for higher or low tractor costs can be made without too much difficulty by dividing the difference in cost by the field rate of accomplishment.

The time available for machine operations by time periods is estimated from weather records in the Bakersfield area. The time available for machine operations is two hours per day less than the number of hours available for farm labor due to time required for nonfield operations and delays. Therefore, the number of hours available for any one machine to work would be: 478 hours in time period T₁; 1,560 hours in time period T₂; and 409 hours in time period T₃ (see Table 6). In addition, some of the harvesting machinery is even more limited with respect to time than that indicated above. The self-propelled combine and the cotton picker are limited to a maximum of 300-350 hours per year.^{2/} The self-propelled baler is limited to 500 hours per year^{3/} and the swather to 700-750 hours per year^{4/} and the potato harvester to 200 hours per year.^{5/}

Techniques Used in the Selection

Even though a number of the operations were consolidated, the magnitude of the selection process is still large. For example, all eight of the wheel tractors can be used for cultivation, the two larger wheel tractors and the three

^{1/} The cost for the wheel tractor is based on a W-35 tractor used 500 hours per year. The cost for the crawler tractor is based on a C-55 tractor used 800 hours per year.

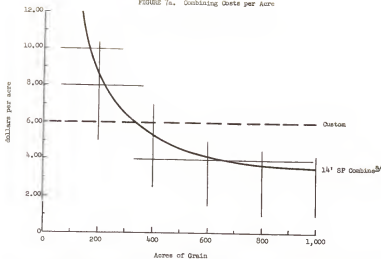
^{2/} The self-propelled combine is limited to 175 hours per year for barley in order to harvest the crop in time to double crop milo. As the combine is used for both barley and milo the total hours per year is 350 hours.

^{3/} The hay baler is limited by the time that atmospheric moisture is sufficiently high to minimize shattering of the hay.

^{4/} The swather is limited by the importance of the timing of the swathing operation.

^{5/} The potato harvester is limited by the potato sheds. Potato digging must be coordinated with the potato shed operations. Consequently, the potato harvester is idle a considerable part of the potato harvest season.

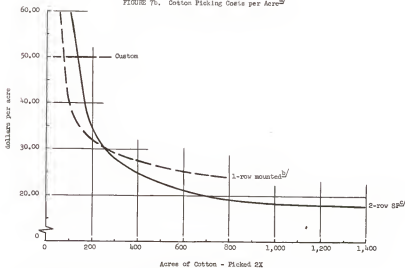
FIGURE 7a. Combining Costs per Acre



b/ Includes a \$1.50 per hour charge of the machine operator and an \$.11 per acre charge for time used in nonfield operations.

Source: Table 5 and Appendix Tables 1 and 5.

FIGURE 7b. Cotton Picking Costs per Acre^{b/}



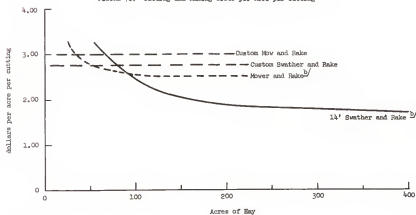
a/ Each acre of cotton is picked two times.

b/ Assumes a constant tractor and labor cost of \$3.50 per hour.

c/ Includes a \$1.50 per hour charge for operator labor.

Source: Table 5 and Appendix Tables 1 and 5.

FIGURE 7c. Cutting and Raking Costs per Acre per Cutting^{b/}

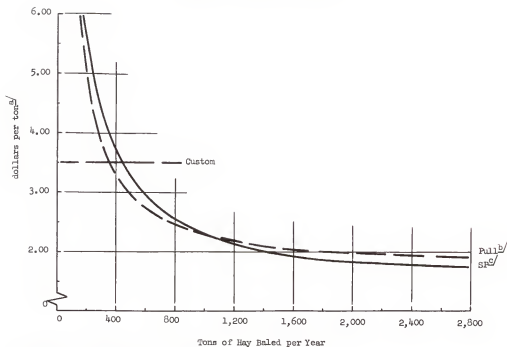


a/ Based on seven cuttings per year.

b/ Includes a \$3.50 per hour cost for labor and tractor in the moving and raking operations and a \$1.50 per hour cost for the swather operator. The labor is paid for two hours per day that the machines are not operating in the field. These curves include the \$3.00 per day charge for this labor.

Source: Table 5 and Appendix Tables 1 and 5.

FIGURE 7d. Baling Costs per Ton



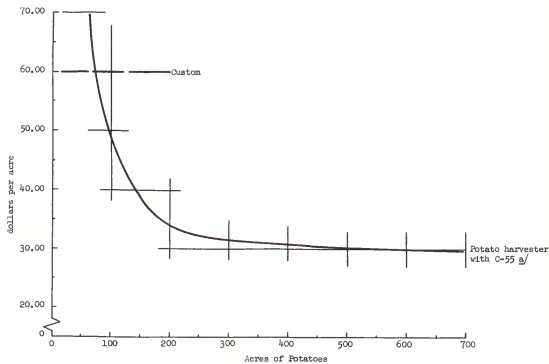
a/ Based on seven ton per acre per year.

b/ Assumes a constant tractor and labor cost of \$3.50 per hour and a 3-wire baler with a motor.

c/ Includes a \$1.50 per hour charge for operator labor.

Source: Table 5 and Appendix Tables 1 and 5.

FIGURE 7e. Potato Harvester Costs per Acre



a/ Assumes a constant tractor and tractor operator cost of \$4.75 per hour. Also seven men on the harvester at \$1.25 per hour.

Source: Table 5 and Appendix Tables 1 and 5.

TABLE 6

Total Machine Hours Available for Each Time Period

Time period	Net work days	Machine hours per day	Total machine hours	Total hours of wages paid ^{a/}
<u>Time period 1</u>				
Dec. 1-15	10.4	8	83.2	104
Dec. 16-31	7.9	8	63.2	79
Jan. 1-15	5.7	8	45.6	57
Jan. 16-31	7.8	8	62.4	78
Feb. 1-14	9.5	8	76.0	95
Feb. 15-28	9.6	8	76.8	96
Mar. 1-15	8.8	8	70.4	88
Subtotal	59.7		477.6	597
<u>Time period 2</u>				
Mar. 16-31	10.0	8	80.0	100
Apr. 1-15	13.0	10	130.0	156
Apr. 16-30	11.0	10	110.0	132
May 1-15	13.0	10	130.0	156
May 16-31	12.0	10	120.0	144
June 1-15	13.0	10	130.0	156
June 16-30	12.0	10	120.0	144
July 1-15	12.0	10	120.0	144
July 16-31	12.0	10	120.0	144
Aug. 1-15	13.0	10	130.0	156
Aug. 16-31	13.0	10	130.0	156
Sept. 1-15	12.0	10	120.0	144
Sept. 16-30	12.0	10	120.0	144
Subtotal	158.0		1,560.0	1,876
<u>Time period 3</u>				
Oct. 1-15	12.0	10	120.0	144
Oct. 16-31	13.0	10	130.0	156
Nov. 1-15	10.6	8	84.8	106
Nov. 16-30	9.3	8	74.4	93
Subtotal	44.9		409.2	499
Total	262.6		2,446.8	2,972

^{a/} Two hours longer per day than the hours available for machine work.

crawler tractors can be used for heavy land preparation, etc. The number of operations to be performed classified by power units plus the custom operations add up to more than 100. In addition, some of the operations are performed in more than one time period.

The technique of linear programming is used to obtain the initial least-cost machinery combinations.^{1/} As machine cost per acre varies with annual use, it was necessary to specify some level of annual use to obtain a cost figure for each machine. For the first "run" of each program the cost was calculated for each piece of machinery at the maximum usage possible for that piece of machinery. The maximum usage was determined either by the hours required to perform a given operation or operations or the maximum hours available for machine operation, whichever one was greater.

The results of the 36 programs were examined and appropriate changes made in the costs per acre and the programs were rerun. The second set of programs furnished an excellent guide to selecting the optimum machinery components. Because of the assumption of perfect divisibility of processes that is employed in the linear programming technique, adjustments were made in the final programs.^{2/} This, of course, necessitated making adjustments in the annual costs for some pieces of machinery. Consequently, both the linear programming technique and the budgeting technique are used in determining the least-cost machinery combination.

The selection of the least-cost combination of crawler tractors is the most difficult phase of the selection process. The results from linear programming include many fractional tractors included in the optimum program. Adjustments for these fractional units, with respect to crawler tractors, are more complicated than for other machinery. This is because rates of accomplishment for the land preparation operations in which crawler tractors are used, are a function of the size of the tractor. The selection problem was made somewhat easier because it was assumed that crawler tractors would be used in all of the heavy and light land preparation operations on the larger farm units.^{3/}

^{1/} There are six farm sizes and three different crop mixes for the constant product mix farms and for the variable product mix farms.

^{2/} The assumption of perfect divisibility results in fractional units being selected in the optimum program. For example, 1.4 tractors of a given size might be selected. Integer programming would have overcome this difficulty.

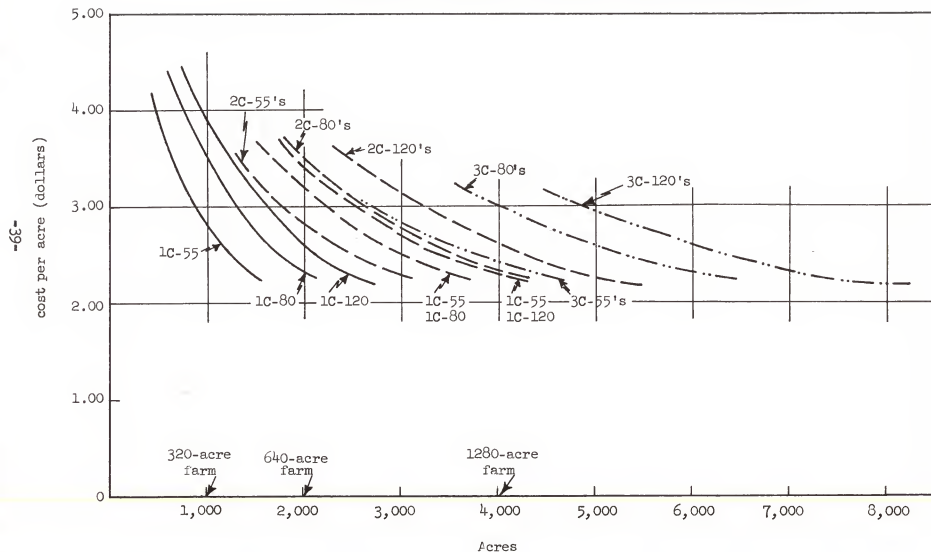
^{3/} Several linear programming problems were run to investigate the possibility of substituting wheel tractors for crawler tractors. This resulted in a substantial increase in the cost of operations.

The selection of the least-cost combination of crawler tractors becomes more difficult as the size of the farm unit increases. The reason for this is that (1) the number of possible tractor combinations becomes greater as farm size increases, and (2) the cost per acre for operating all crawler tractors is approximately the same when tractors are used at capacity.^{1/} The following procedure is typical of the budgeting procedure used to adjust the crawler tractor component obtained from linear programming.

The costs per acre of different crawler tractor combinations for light and heavy land preparation are presented in Figure 8 for farms with a constant cotton-alfalfa product mix. Only the costs of the tractors and drivers are included. The cost of the implements is approximately equal per acre and is not included. The lower limits of the curves are determined by the hours of annual use possible under the constant cotton-alfalfa product mix. The 320-acre farm has 964 acres of light and heavy land preparation to perform. It is quite obvious that the C-55 crawler tractor is the least-cost tractor for the 320-acre farm. The 640-acre farm has 1,928 hours of light and heavy land preparation to perform. Again it is quite obvious that the C-80 is the least-cost tractor for the size of farm within the time available. The 1,280-acre farm has 3,856 acres of light and heavy land preparation to perform. One C-55 and one C-80 are not quite sufficient to perform these operations in the limited time periods. Consequently, one C-55 and one C-120 is the least-cost source of adequate power for the 1,280-acre farm. However, two C-80 crawler tractors are almost as satisfactory because the cost per acre is only \$.03 higher. Three C-55 crawler tractors would have performed the required operations at approximately \$1.10 per acre more than the least-cost tractor combination (see Figure 8). (All of the possible crawler tractor combinations are not presented but the greater the acreage the larger the number of possible combinations.) A curve could be constructed presenting the least-cost combination of crawler tractors for light and heavy land preparation. It would be a scalloped curve with the scallops diminishing in size as acreage increased. This curve would approximate a straight line horizontal to the acres axis at the large acreages. This indicates that the larger farms can select their tractor combinations to utilize all of their crawler tractors to near capacity.

^{1/} Capacity is a function of the amount of work performed by time periods. Even though a tractor may remain idle much of the year, it can be used to capacity in one or more time periods.

FIGURE 8. Cost per Acre of Crawler Tractors for Light and Heavy Land Preparation, Farms with a Constant Cotton-Alfalfa Product Mix



Machinery Combinations Selected

The least-cost machinery combinations for constant product mix farms are presented in Tables 7 through 9 and for the variable product mix farms in Appendix Tables 7 through 9. The least-cost machinery combinations are quite similar for the constant and the variable product mix farms.^{1/} These tables furnish a summary of the operations performed by each tractor and self-propelled machine. Whether some of the operations were performed by a W-25 or a W-35 wheel tractor was an arbitrary decision. The man hours of labor associated with machinery is also presented in these tables. The acres of each crop are presented for reference purposes. The acres for each operation were obtained by multiplying the acres of a crop (or crops) by the number of times that the operation is performed each year for the production of that crop (or crops). For example, cotton is picked twice. Therefore, the acreage of cotton is multiplied by two in order to obtain the acres for the cotton picking operation.

Number, Size, and Annual Use of Machinery

It is somewhat difficult to compare the physical machinery components from the previous tables. Consequently, the information on number, size, and annual use of tractors and self-propelled machinery was summarized and presented in Table 10. There are some differences in the machinery combinations by type of crops produced. However, most of the differences result from the machinery required to harvest the different crops. This indicates that a farm operator could change his cropping program without drastically changing the equipment component.

It is less costly for the 80-acre and the 160-acre farming units to have the heavy land preparation and most of the harvesting performed on a custom basis rather than owning the machinery and performing these operations. The alfalfa acreage is large enough on two of the 160-acre farms to economically justify a pull type baler. An extra tractor is required on these two farms, however, as a result of adding the baling operation. The most important difference between the 80-acre and the 160-acre farm units is that the latter farm units use most of their machines twice as many hours per year as the smaller farms. This has a considerable effect upon the overhead costs per acre.

^{1/} Consequently, it does not appear necessary to present the tables for the variable product mix farms in the text.

TABLE 7

a/ The cost per hour includes only the cost of cotton trailers. The labor on this operation is usually supervisory in nature and truck cost is included with automotive equipment.

b/ Total man-hours required to keep machinery operating the designated hours. This includes multiple man operations as well as losses associated with nonfield operations.

c/ Man-hours lost in nonfield operations, e.g., to and from field, lunch, unusual delays from breakdown, etc.

d/ See Appendix Table 3.

Machinery Costs, Power Units, and Labor Associated with Machine Operations
by Size of Farm, Constant Product Mix, Cotton - Alfalfa - Potatoes

a/ The cost per hour includes only the cost of cotton trailers. The labor on this operation is usually supervisory in nature and truck cost is included with automotive equipment.

b/ Total man-hours required to keep machinery operating the designated hours. This includes multiple man operations as well as losses associated with nonfield operations.

c/ Man-hours lost in nonfield operations, e.g., to and from field, lunch, unusual delays from breakdown, etc.

d/ See Appendix Table 3.

Source: Tables 2, 4, 5 and Figures 5, 6, and 7.

TABLE 9

Machinery Costs, Power Units, and Labor Associated with Machine Operations by Size of Farm, Constant Product Mix, Cotton - Alfalfa - Barley (de) - Milo (de) Farms

Item	Acres	Power unit	Man-hours	Machine hours	Machine cost per unit	Size of farm (total acres)										
						Acres	Power unit	Man-hours	Machine hours	Machine cost per unit	Acres	Power unit	Man-hours	Machine hours	Machine cost per unit	
80																
dollars																
Crops																
Cotton	30					60					120					
Alfalfa	25					50					100					
Barley (de)	20					40					80					
Milo (de)	20					40					80					
Total	95					190					380					
Operations																
Pick cotton	60	Custom			25.00/ac	120	1-row picker	200	171	10.90/hr	240	1-row picker	400	342	8.05/hr	
Combine barley - milo	40	Custom			6.00/ac	80	Custom			6.00/ac	160	Custom			6.00/ac	
Bale alfalfa	175	Custom			3.50/ac	350	Custom			3.50/ac	700	W-35	109	88	17.30/hr	
Light land preparation	258	W-35	323	258	.70/hr	516	W-35	646	516	.60/hr	1,032	C-55	516	413	1.15/hr	
Heavy land preparation	175	W-35			6.50/ac	90	Custom			6.50/ac	180	C-55	138	113	2.10/hr	
Mow alfalfa	175	W-35	66	55	1.26/hr	350	W-25			1.32	110	700	Swather	207	175	6.00/hr
Rake alfalfa	175	W-35	55	46	1.57/hr	350	W-25			1.10	92	700	W-25	110	92	1.25/hr
Cultivate cotton and milo	220	W-35	51	42	1.86/hr	440	W-25			1.02	84	880	W-25	204	168	.99/hr
Haul cotton &/	60	Truck	111	86	1.95/hr	120	Truck			222	172	340	Truck	344	280	.90/hr
Misc. light operations	330	W-35	89	75	1.60/hr	660	W-25			178	150	1,320	W-25	356	300	1.35/hr
Total b/			699	562		660		1,290	1,295				2,464	8,095		
{ Labor losses not associated with field operations }			89					213					385			
Power equipment																
25 HP wheel tractor												1		560	3.05/hr	
35 HP wheel tractor	1			476	3.65/hr	1		1,123	2.75/hr	1		1		430	3.90/hr	
55 HP crawler tractor												1		586	5.75/hr	
80 HP crawler tractor																
120 HP crawler tractor																
Self-propelled baler																
Self-propelled cotton picker (2-row)																
Self-propelled combine												1				
Self-propelled sweeper																
Automotive equipment &/	80				8.44/ac	160				5.34/ac	320			175	see row 5.00/ac	
640																
1,280																
3,200																
dollars																
Crops																
Cotton	240					480					1,200					
Alfalfa	200					400					1,000					
Barley (de)	160					320					800					
Milo (de)	160					320					800					
Total	760					1,520					3,800					
Operations																
Pick cotton	480	2-row picker	400	320	17.40/hr	960	2-row picker	800	640	17.40/hr	2,400	2-row picker	2,000	1,600	17.40/hr	
Combine barley - milo	320	Custom			6.00/ac	640	SP combine	274	229	11.00/hr	1,600	SP combine	886	571	10.30/hr	
Bale alfalfa	1,400	W-35	218	175	12.60/hr	2,800	SP baler	936	311	12.11/hr	7,000	SP baler	966	778	11.76/hr	
Light land preparation	2,064	C-60	794	685	.70/hr	4,128	C-60	1,588	1,250	1.87/hr	10,320	C-120	2,577	2,067	1.42/hr	
Heavy land preparation	1,400	C-90	276	226	1.42/hr	2,800	C-90	558	452	1.85/hr	1,800	C-120	818	643	2.10/hr	
Mow alfalfa	480	Swather	480	320	4.75/hr	960	Swather	840	700	4.15/hr	1,600	Swather	2,100	1,750	3.90/hr	
Rake alfalfa	1,400	W-35	220	158	.70/hr	2,800	W-25	410	368	.70/hr	1,600	W-25	1,120	920	.69/hr	
Cultivate cotton and milo	1,760	W-25	408	336	.80/hr	3,520	W-25	616	672	.80/hr	1,600	W-25	2,040	1,680	.76/hr	
Haul cotton &/	480	Truck	886	688	.80/hr	960	Truck	1,776	1,376	.72/hr	2,400	Truck	4,440	3,440	.72/hr	
Misc. light operations	2,640	W-25	712	600	1.10/hr	5,280	W-25	1,488	1,200	1.10/hr	13,600	W-25	3,560	3,000	1.13/hr	
Total b/			4,336	3,504				8,896	7,198				16,883	16,330		
{ Labor losses not associated with field operations }			589					1,090					2,805			
Power equipment																
25 HP wheel tractor	1			936	2.80/hr	2			2,840	2.75/hr	4			5,600	2.70/hr	
35 HP wheel tractor	1			359	4.10/hr											
55 HP crawler tractor																
80 HP crawler tractor	1			651	6.30/hr	2			1,708	6.30/hr	1			470	8.70/hr	
120 HP crawler tractor																
Self-propelled baler												1		2,730	7.65/hr	
Self-propelled cotton picker (2-row)	1			380	see pick cotton	2			311	see bale cotton	3			1,600	see pick cotton	
Self-propelled combine									640	see pick cotton	2					
Self-propelled sweeper									289	see combine cotton	2			571	see combine cotton	
Automotive equipment &/	640			350	see row 3.72/ac	1,280			700	see row 3.03/ac	3,200			1,750	see row 2.13/ac	

a/ The cost per hour includes only the cost of cotton trailers. The labor on this operation is usually supervisory in nature and truck cost is included with automotive equipment.

b/ Total man-hours required to keep machinery operating the designated hours. This includes multiple man operations as well as losses associated with nonfield operations.

c/ Man-hours lost in nonfield operations, e.g., to and from field, lunch, unusual delays from breakdown, etc.

d/ See Appendix Table 3.

Source: Tables 2, 4, 5 and Figures 5, 6, and 7.

TABLE 10

Number, Size, and Hours of Annual Use for Tractors and Self-Propelled Machinery by Product Mix and Size of Farm ^{a/}

Farm size and power units	Constant product mix						Variable product mix					
	Cotton-alfalfa		Cotton-alfalfa-potatoes		Cotton-alfalfa-barley/milo		Cotton-alfalfa		Cotton-alfalfa-potatoes		Cotton-alfalfa-barley/milo	
	no.	hrs. ^{b/}	no.	hrs. ^{b/}	no.	hrs. ^{b/}	no.	hrs. ^{b/}	no.	hrs. ^{b/}	no.	hrs. ^{b/}
<u>80-acre farms</u>												
W-35	1	451	1	447	1	476	1	457	1	457	1	478
<u>160-acre farms</u>												
W-25	1	612	1	478	0		0	0	0	0	0	0
W-35	1	626	1	652	1	1,123	1	1,166	1	1,136	1	1,139
<u>320-acre farms</u>												
W-25	1	498	1	496	1	560	0	0	0	0	0	0
W-35	1	500	1	472	1	430	1	996	1	960	1	1,279
C-55	1	435	1	466	1	526	1	261	1	473	1	531
Swather, SP	1	315	1	259	1	175	1	315	1	245	0	0
<u>640-acre farms</u>												
W-25	1	996	1	992	1	936	1	943	1	942	1	604
W-35	0	0	0	0	1	359	0	0	0	0	1	955
C-55	0	0	0	0	0	0	0	0	2	920	0	0
C-80	1	661	1	706	1	851	1	642	0	0	1	699
Swather, SP	1	630	1	518	1	350	1	676	1	536	1	369
Cotton picker, SP	1	320	1	320	1	320	1	285	1	285	1	285
Baler, SP	1	280	1	230	0	0	1	300	1	238	0	0
Potato harvester	0	0	0	0	0	0	0	0	1	67	0	0
<u>1,280-acre farms</u>												
W-25	2	1,992	2	1,988	2	2,240	2	1,759	2	1,756	2	2,078
C-55	1	600	1	773	0	0	1	539	2	1,296	2	1,086
C-80	0	0	0	0	2	1,702	0	0	0	0	1	743
C-120	1	666	1	699	0	0	1	528	1	672	0	0
Swather, SP	2	1,260	2	1,036	1	700	2	1,474	2	1,193	1	796
Cotton picker, SP	2	640	2	640	2	640	2	477	2	477	2	477
Baler, SP	2	560	2	460	1	311	2	654	2	530	1	398
Potato harvester	0	0	1	107	0	0	0	0	1	134	0	0
Combine, SP	0	0	0	0	1	229	0	0	0	0	1	276
<u>3,200-acre farms</u>												
W-25	4	4,980	4	4,530	4	5,600	4	4,222	4	4,217	4	5,039
C-55	1	400	1	1,099	0	0	2	1,300	3	1,875	2	1,195
C-80	0	0	0	0	1	470	0	0	0	0	0	0
C-120	3	2,319	3	2,243	3	2,730	2	1,555	3	2,376	3	2,293
Swather, SP	4	3,150	4	2,590	2	1,750	5	3,850	4	3,150	3	2,121
Cotton picker, SP	5	1,600	5	1,600	5	1,600	4	1,067	4	1,067	4	1,067
Baler, SP	4	1,400	4	1,150	2	778	5	1,709	4	1,399	3	1,061
Potato harvester	0	0	2	267	0	0	0	0	2	333	0	0
Combine, SP	0	0	0	0	2	571	0	0	0	0	2	706

^{a/} The potato harvester is not self-propelled but was included because it is a relatively expensive machine.

^{b/} The hours are total hours. To calculate the hours per machine, the total hours must be divided by the number of machines.

Source: Tables 7, 8, and 9.

The 320-acre farms are of sufficient size to perform their own heavy land preparation operations and some of their own harvesting operations. The 640-acre farming units require more power for the land preparation operations and can economically justify additional self-propelled harvesting machines. The small wheel tractors are just about used to their capacity with respect to time available in limited time periods.

The 1,280-acre farms are sufficiently large to enable them to economically justify all of the self-propelled machinery and to use the largest size of crawler tractor. In fact, multiples of some of the self-propelled machines are required. Other self-propelled machines are more fully utilized in the 1,280-acre farming units than on the 640-acre farming units. The 3,200-acre farms use essentially the same size of tractors and self-propelled machines as do the 1,280-acre farms. However, the larger farms generally use the machines a larger number of hours than do the smaller farms. The limits placed on the annual use of self-propelled machines becomes very important on the larger farms in determining the number of machines required.

Because automotive equipment is considered machinery it is included at this point. The number of trucks, trailers, and implement carryalls required are determined from survey data and secondary sources (see Appendix Table 9). The costs are presented in Appendix Tables 3 and 9.

Effects of Labor on Machinery Selection

In the selection of the least-cost machinery combinations it is specified that all of the labor required can be obtained for the "going wage rate." In addition, each hour of labor required is costed at the "going wage rate." These assumptions are an oversimplification of reality. Farmers are faced with various labor supply and management problems. On multiple-man farming units labor may be hired on a full-time or temporary basis. The operator may also be considered as being hired on the full-time basis. The trend in recent years has been for farms to hire more men on the full-time basis and rely less on seasonal or temporary labor. Mechanization has been a large factor in this trend.

Full-time labor can be paid on an hourly basis or an annual basis. In both instances the operator must manage the full-time hired labor so as to keep them as fully employed as possible. The opportunity cost is important in this instance. The full-time laborer paid on an hourly basis may look for

employment elsewhere if the hours worked fall below what he might obtain elsewhere. The full-time laborer paid on an annual basis will be paid regardless of whether or not he is productively employed. Consequently, his wages must be looked at in terms of a fixed cost within the production period.

In addition to the problems of managing the full-time labor, the operator has the problem of obtaining the seasonal or temporary labor. It may also be a problem of obtaining the quality of labor that the operator believes is adequate for certain machine operations. Thus, the operator must obtain temporary machine operators, who he feels are qualified for a relatively limited time period.

The considerations of utilizing the full-time employees and obtaining temporary employees may result in the operator selecting a machinery combination that differs slightly from the least-cost machinery combinations presented.

In order to evaluate the effect that labor might have upon the selection of machinery, it would be necessary to construct a chart showing the amount of labor required by time periods for a combination of machines and the amount of labor available from full-time employees. The amount of temporary labor required and time periods when full-time employees were not fully utilized could then be ascertained. The machinery component then could be reevaluated in view of these labor shortages or excesses. The opportunity cost for full-time employees, especially those on an annual salary, would be low (or perhaps zero) in those time periods when there was excess labor. Consequently, a smaller machine or machinery combination might be used than that indicated by the least-cost machinery combinations that were selected in the previous section. In other instances, a farm operator may decide that it is advantageous to purchase a larger machine or machinery combination than that dictated by the least-cost combination if it will mean that no temporary labor will need to be hired for that operation.

The amount of available labor may also be important in determining whether or not certain operations are performed on a custom basis. If there is an excess of labor then the cost of the operation should not include the labor (or a lower labor cost should be used) when making the comparison with the cost of custom operations. If temporary labor must be hired just for a particular operation, then the operator may decide that it is advantageous to hire the operation performed on a custom basis.

Adjustments are not made in this report that might result from the labor supply. It is important to realize that the labor component can and will influence the machinery selection made by the farm operator. It is also important to use the opportunity cost concept in pricing a more or less fixed labor supply in periods when labor is not fully utilized. The effect that temporary labor requirements has upon the operator's decision must also be recognized.

LEAST-COST AND TYPICAL MACHINERY COMBINATIONS

The least-cost machinery combinations were assembled on the basis of time-liness and costs. The authors also believe that these machinery combinations are workable in that the hours of time available for machine operation are quite limiting. Thus, the least-cost machinery combinations could perform the necessary operations for a considerably larger acreage if double shifts are used in the critical time periods. However, excess capacity in the form of stand-by machines were not "built into" the machinery combinations selected. How do these least-cost machinery combinations compare with the machinery combinations that presently exist on cash-crop farms in the Southern San Joaquin Valley? It is the purpose of this section to make this comparison and to examine the effects of the differences on investment and annual costs.^{1/}

Selection of Typical Machinery Combinations

Data for constructing typical machinery combinations were obtained from a random stratified sample of 112 cotton cash-crop farms in Kern County. This study, part of a capital-labor study, was made concurrently with the economies of size study in the same area.^{2/} The acreages of the crops used for the variable product mix farms are based upon the cropping programs of farms in the capital-labor study. The cotton-alfalfa-barley (dc)-milo (dc) product mix is the most common mix for farms in this area. Consequently, the typical machinery combinations presented in this report are those being used in the production of this variable product mix (see Table 9 for the operations to be performed).

The selection of a typical machinery component is somewhat arbitrary. Farms were placed in size groups to correspond with the size of farms used for

^{1/} It is pointed out in the following discussion that caution must be used in making these comparisons. A different set of assumptions might have resulted in different least-cost machinery combinations. Also, there are certain noncost considerations that may motivate decisions on machinery requirements.

^{2/} Unpublished data from the Capital-Labor Study, Department of Agricultural Economics, Davis.

the least-cost analysis. The average number of tractors per size group is used as the selection criterion for tractors. The size of tractors are placed into the size categories presented in Appendix Table 1. This criterion was also used in the selection of nonharvest machines. Adjustments were made for farms producing a product mix considerably different from the typical product mix. For the machines used in harvest operation the criterion is used that the machine appears on one out of three farms before it is considered typical. The reason for this relatively low percentage of appearance requirement is that the crops and acreages of crops vary considerably among farms and these are all important in determining harvest machinery requirements. Even so some of the larger and newer pieces of harvesting equipment are not included in the typical machinery components.

Comparison between Machinery Combinations Selected

The typical and the least-cost machinery combinations selected for cotton-alfalfa-barley (dc)-milo (dc) farms are presented in Table 11.^{1/} If it can be assumed that the least-cost machinery combination is an adequate measure of "what should be," then, the typical 80-acre farm has three times the number of tractors and power needed. The typical 80-acre farm also has a one-row mounted cotton picker which is not economically justified when considering the possibility of custom picking.

The typical 160-acre unit has excess capacity in both wheel and crawler tractors. The crawler tractor is needed only for the heavy land preparation operations. A wheel tractor can perform the light land preparation operations. The 160-acre farm unit does not have a sufficient volume of heavy work to justify owning the crawler tractor. The wheel tractors, along with custom operations for heavy land preparation, results in a lower cost than ownership of a crawler tractor.

The 320-acre and the 640-acre typical farm units also have excess capacity in wheel tractors. The 1,280-acre typical farm unit has an extreme excess capacity in wheel tractors while it has about the right number and sizes of crawler tractors. Only two wheel tractors are required compared to the nine found

^{1/} The hours of annual use shown for the tractors in the typical machinery combinations are divided among tractors in an arbitrary manner. In most instances, it is assumed that the hours of annual use for wheel tractors is equally divided among the tractors.

TABLE 11

Number and Hours Annual Use of Tractors and Major Harvesting Machines
for Least-Cost and Typical Machinery Combinations by Farm Size

Farm size and power unit	Least-cost		Typical		Excess machines number
	number	hours ^{a/}	number	estimated hours ^{a/}	
<u>80-acre farms</u>					
W-25	0	0	1	191	1
W-35	1	478	2	382	1
Cotton picker, 1-row	0	0	1	105	1
<u>160-acre farms</u>					
W-35	1	1,139	1	307	0
W-45	0	0	1	307	1
C-55	0	0	1	267	1
Cotton picker, 1-row	1	183	1	183	0
<u>320-acre farms</u>					
W-25	0	0	1	426	1
W-35	1	1,279	1	426	0
W-45	0	0	1	426	1
C-55	1	531	1	531	0
Cotton picker, 1-row	1	342	1	342	0
Baler-pull type	1	98	0	0	-1
<u>640-acre farms</u>					
W-25	1	604	1	561	0
W-35	1	955	1	561	0
W-45	0	0	2	1,122	2
C-80	1	699	1	699	0
Cotton picker, 1-row	0	0	1	195	1
Cotton picker, 2-row	1	285	1	194	0
Combine, SP	0	0	1	125	1
Swather, SP	1	369	0	0	-1
Baler-pull type	1	164	0	0	
<u>1,280-acre farms</u>					
W-25	2	2,078	2	896	0
W-35	0	0	2	896	2
W-45	0	0	2	896	2
W-55	0	0	1	493	1
C-55	2	1,086	2	1,086	0
C-80	1	743	1	743	0
Cotton picker, 2-row	2	477	2	477	0
Combine, SP	1	276	1	276	0
Swather, SP	1	796	0	0	-1
Baler, SP	1	398	0	0	-1

^{a/} The total hours are presented. When two machines of the same type are indicated it is necessary to divide by two in order to obtain the hours of use per machine.

on the typical 1,280-acre farm. Because of the lack of data an adequate comparison could not be made for the 3,200-acre farms.

Not only do the typical machinery combinations include more wheel tractors than the least-cost combinations, but the wheel tractors are also larger (have a higher horsepower rating). The typical farm units do not have an excess of hay harvesting machines. In fact, the least-cost machinery combinations, for the three largest farm units, include special hay harvesting machines not included in the typical machinery combinations.

A comparison was made between the least-cost and the typical machinery combinations with respect to the machines not included in Table 11. This includes tillage, planting, and automotive machines as well as some of the less expensive machines used in harvesting such as cotton trailers, hay rakes, and hay mowers. This comparison indicated only minor differences between the least-cost and the typical combinations for these machines or implements.^{1/} Consequently, it is assumed that the investment and costs for these machines or implements are equal when making the comparison between least-cost and typical machinery combinations.

The comparisons made above and the comparisons that follow must be viewed with caution. Comparisons are made on the basis of machines of average age and condition.^{2/} If a number of the farms keep one or more older wheel tractors for stand-by work, the annual costs and investment in these tractors would be overstated for the typical farm units. The effect that the labor component might have upon the machinery component has been mentioned previously.

Comparison of Machinery Investments and Custom Operations

The investment in machinery and the operations performed on a custom basis must be considered simultaneously as the amount of custom work affects the investment required to perform the farming operations. Comparisons between the least-cost and the typical farming operations with respect to machinery investment and custom work are presented in Table 12 for the five farm sizes. The machinery investment is lower for the least-cost machinery combinations in each

^{1/} Many of the farms in the survey had machinery that was not being used, especially tillage machines. These machines were not included in the machinery component for typical farms. Only those machines used during the past year were included.

^{2/} Machinery is costed at 1962 prices. The investment in machinery is assumed to be one-half of the new price in 1962.

TABLE 12

Estimated Machinery Investments and Cost of Custom Operations for
Least-Cost and Typical Machinery Combinations by Farm Size

Size of farm acres	Machinery investment ^{a/}		Custom work	
	Total	Per acre	Total	Per acre
dollars				
least-cost combination				
80	9,700	121.50	2,817	35.20 ^{b/}
160	15,150	94.70	2,198	13.70 ^{c/}
320	27,850	87.00	1,008	3.10 ^{d/}
640	44,600	69.70	2,099	3.30 ^{d/}
1,280	78,750	61.50	0	0
typical combination				
80	16,700	208.80	1,065	13.30 ^{e/}
160	22,600	141.20	1,606	10.00 ^{e/}
320	31,400	98.10	3,360	10.50 ^{e/}
640	54,250	84.80	5,171	8.10 ^{f/}
1,280	80,850	63.20	11,149	8.70 ^{f/}

a/ All machinery is priced at the 1962 price level. It is assumed that present value is one-half of new cost. The machines are one-half depreciated out. Therefore, the investment figures presented are one-half of the new cost in 1962.

b/ Custom work includes heavy land preparation and the harvesting of cotton, alfalfa, barley, and milo.

c/ Custom work includes heavy land preparation and the harvesting of alfalfa, barley, and milo.

d/ Custom work includes the harvesting of milo and barley.

e/ Custom work includes the harvesting of alfalfa, barley, and milo.

f/ Custom work includes the harvesting of alfalfa.

size group. This is primarily a result of the larger number of wheel tractors on the typical farm units. Even though the larger least-cost farm units have specialized hay harvesting machines not on the typical farms, the investment in wheel tractors on the latter farms more than compensates for this investment in haying machinery. The per acre cost of custom work for the least-cost farm units decreases from \$35.20 on the 80-acre unit to \$0.00 on the 1,280-acre unit while the per acre cost of custom work remains rather constant over all farm sizes for the typical farm units. The effects of the investment in the one-row cotton picker for the 80-acre typical unit and the investment in the self-propelled combine for the 640-acre typical unit are rather evident in comparing these with the least-cost machinery investments on the same farm sizes.

Comparison of Annual Costs

The annual per acre costs associated with machinery operations are presented in Table 13 for the least-cost and the typical farm units. Costs for the typical machinery combinations range from \$3.95 to \$14.05 per acre higher than the least-cost machinery combinations. Per acre machinery costs for typical farm units continue to decrease as farm size increases. This is consistent with the least-cost machinery combinations. However, the smallest difference in costs between the typical and the least-cost combinations occurs for the 320-acre farm units. Most of this difference can be attributed to the excess of wheel tractors on the typical 320-acre unit. Although the 320-acre least-cost machinery combinations includes a pull-type hay baler, the difference in costs between this and custom baling is rather small. As farm size increases beyond 320 acres, the decrease in costs that results from owning specialized haying machinery becomes greater. The typical farm units do not own this specialized machinery. Hence, differences in per acre costs increase between least-cost and typical farm units as size increases beyond 320 acres.

The effect on annual per acre costs of the increase in machinery investments is presented in the last column in Table 13. This is rather large for the two smallest farm sizes and practically nil for the 1,280-acre farm unit.

Cost of Overcapacity

There are a number of reasons that a farm operator might give for having an excess of machinery over that required to perform the required operations. Reasons most often given are the insurance factor and convenience.

TABLE 13

Estimated Differences in per Acre Machinery Costs Between
Least-Cost and Typical Machinery Combinations

Size of farm	Total machinery costs ^{a/}		Increase in costs for typical machinery combinations due to:	
	Least-cost combination	Typical combination	Differences in tractors and harvesting operations ^{b/}	Interest on machinery investments ^{c/}
acres	dollars per acre			
80	75.60	89.65	8.80	5.25
160	61.30	67.30	3.70	2.80
320	52.30	56.25	3.30	.65
640	40.70	51.10	9.50	.90
1,280	36.50	45.60	9.00	.10

^{a/} Total machinery costs include operating and overhead charges as well as the cost of labor associated with machinery operations.

^{b/} This includes all cost of operating tractors and harvesting machines. Also, the cost of custom operations are included in these figures even though some of the custom operations are not harvest operations on the smaller farm sizes.

^{c/} This was calculated using a 6 percent interest rate for the difference in machinery investments between the least-cost and the typical machinery combinations.

How valid is the argument of the insurance factor? The insurance being considered here is the informal insurance of having excess capacity or standby machines in the advent of a breakdown or adverse weather conditions. The least-cost machinery component is based upon the assumption that the machines are not worked over ten hours per day and that the machines are idle on Sundays and holidays. The weather conditions assumed in determining the number of work days available were less favorable than the average conditions in recent years. Thus, an informal insurance was incorporated in the model used in selecting the least-cost machinery combinations. The possibility of working two shifts or a seven-day week does exist to meet unusual adverse conditions.

Convenience undoubtedly is one of the major reasons why the typical farm units had more wheel tractors than was indicated necessary by the least-cost machinery analysis. May and June are months when wheel tractors are performing many different operations. Mowing, raking, cultivating, and many miscellaneous operations are performed in this time period. This necessitates the changing of implements each time a different operation is performed. Evidently, many farmers have chosen to own more wheel tractors and avoid the problems and inconvenience of changing implements. The least-cost machinery combinations were selected under conditions that made an allowance for the time required to change implements. However, this time period (T_2) is not usually a critical time period for machinery. That is, there is usually excess time available to perform these operations so it must be a matter of convenience. The 320-acre farm operation is the size of farm that is the closest to being marginal in this respect. Although an allowance is not made for time saved by not changing implements so often, e.g., having one tractor for cultivating only, a cursory analysis indicates that it would be unlikely to offset the cost of owning another tractor.

Overcapacity in numbers and power requirements exist primarily in wheel tractors. There are only a few instances of excess capacity in crawler tractors and harvesting equipment. These machines have a high investment cost plus a high annual operating cost. Perhaps farmers have given closer attention to not obtaining excess capacity in these machines. Wheel tractors are relatively less expensive and farmers may be less discriminatory in their analysis of whether to buy an additional wheel tractor.

What is the cost of excess capacity in farm machinery of the typical machinery combinations as compared to the least-cost machinery combinations?

It is difficult to determine this cost as a number of different factors influence the per acre costs presented in Table 13. However, the analysis indicates that the excess wheel tractors on the 320-acre typical farm unit increases per acre cost by approximately \$4.00. When the difference in hay harvesting costs is accounted for, the cost of the excess wheel tractors on the 1,280-acre typical farm unit is between \$5.00 and \$6.00 per acre. The per acre costs for excess capacity is even greater for the other three farm sizes. The price for convenience and informal insurance appears to be rather large. This assumes that additional tractors do not result in increased yields through better timing of cultural and harvest operations.

TECHNICAL ECONOMIES ASSOCIATED WITH MACHINERY

The total per acre annual machinery costs are presented in Table 14 for the 36 different farming units. The technical economies associated with machinery for the constant and variable product mixes for the three crop programs are presented in Figures 9 through 11. It is necessary to be somewhat cautious in interpreting these curves, particularly the variable product mix curves. Machinery is only one segment of the farm organization. To use these curves to indicate the maximum net returns per acre would be an incorrect interpretation. The curves indicate the least-cost machinery combinations that were constructed for various levels of output. Acres are an acceptable measure for the constant product mix farms but a somewhat doubtful measure of output for the variable product mix farms. For the latter farms the average gross returns would not be constant per acre but would be sloping downward to the right. This is a result of the proportion of high value crops in the product mix decreasing as the farm size increases.

The annual machinery costs per acre for the 80-acre farming units are approximately one and one-half times the per acre cost for 3,200-acre farming units. The machinery costs per acre decrease quite rapidly up to the 640-acre units. After 640 acres the rate of decrease in per acre costs is considerably less. However, the annual per acre machinery costs for the 640-acre farming units are ten percent (or more) greater than the machinery costs for the 3,200-acre units. Relative to the decrease in per acre costs that occur as farm size increases from the 80-acre farms the decrease in per acre costs after 640 acres appears to be rather small. Measured in terms of total costs, the difference becomes greater. For example, if the costs for the 3,200-acre farm units were

TABLE 14

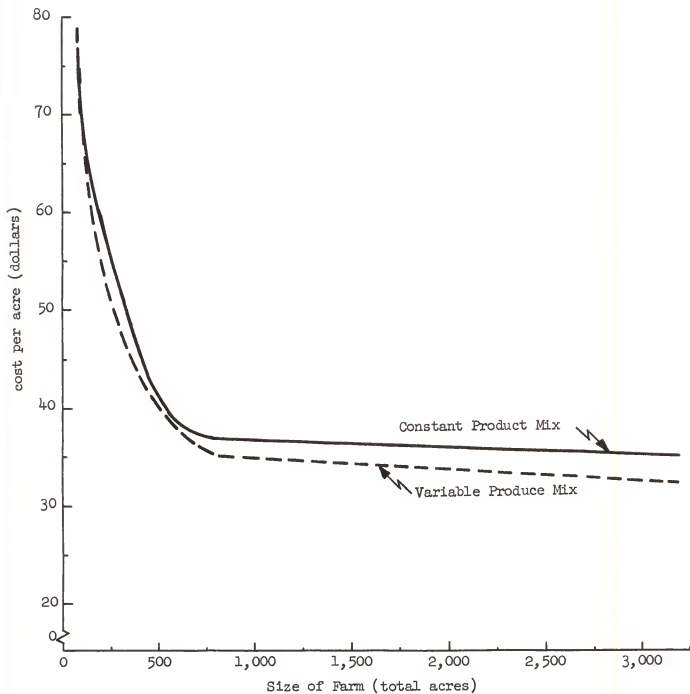
Annual Machinery Cost and Investment by Crop Program,
Product Mix and Size of Farm

Item	Constant product mix				Variable product mix			
	Machinery investment		Annual machinery costs		Machinery investment		Annual machinery costs	
	Total ^{a/}	Per acre	total	Per acre	Total ^{a/}	Per acre	Total	Per acre
dollars								
<u>Crop program 1 (C-A)</u>								
80	18,405	231.06	6,094	76.18	18,405	231.06	6,278	78.48
160	36,885	230.53	10,032	62.70	34,785	217.41	9,401	58.76
320	61,885	193.39	16,363	51.13	59,285	185.27	14,950	46.72
640	86,948	135.86	24,134	37.71	86,948	135.86	23,657	36.96
1,280	160,741	125.58	46,736	36.51	158,328	123.69	44,177	34.51
3,200	354,340	110.73	111,984	35.00	333,150	104.11	103,035	32.20
<u>Crop program 2 (C-A-P)</u>								
80	19,735	246.69	6,358	79.48	19,735	246.69	6,240	78.00
160	38,635	241.47	10,742	67.14	36,035	225.22	10,700	66.88
320	63,135	197.30	17,303	54.07	60,535	189.17	17,317	54.12
640	88,198	137.81	27,273	42.61	106,065	165.73	26,350	41.17
1,280	177,345	138.55	49,792	38.90	185,815	145.17	51,938	40.53
3,200	388,390	121.37	119,548	37.36	380,070	118.77	118,675	37.09
<u>Crop program 3 (C-A-Bdc-Mdc)</u>								
80	19,385	242.31	5,855	73.19	19,385	242.31	6,051	75.64
160	32,885	205.53	10,039	62.74	30,285	189.28	9,801	61.26
320	62,885	196.52	17,438	54.49	55,735	174.17	16,743	52.32
640	89,248	139.45	26,148	40.86	89,248	139.45	26,042	40.69
1,280	165,041	128.94	47,893	37.42	157,478	123.03	46,631	36.47
3,200	371,470	116.00	109,143	34.11	341,150	106.61	107,372	33.55

^{a/} Based upon 1962 prices. The machinery components in terms of the number of implements required by size of farm were selected so that sufficient machinery would be available to perform the required operations within the limited time periods.

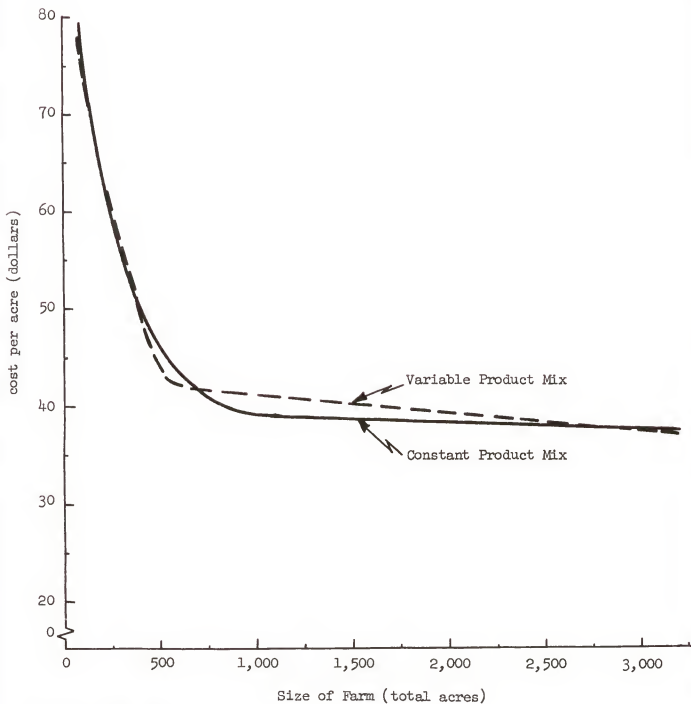
Source: Faris, J. Edwin and David L. Armstrong, Economies Associated with Size, Kern County Cash-Crop Farms, Berkeley: University of California, Agricultural Experiment Station, Giannini Foundation Research Report No. 269, December 1963.

FIGURE 9. Technical Economies Associated with Machinery,
Constant and Variable Product Mix,
Cotton-Alfalfa Farms



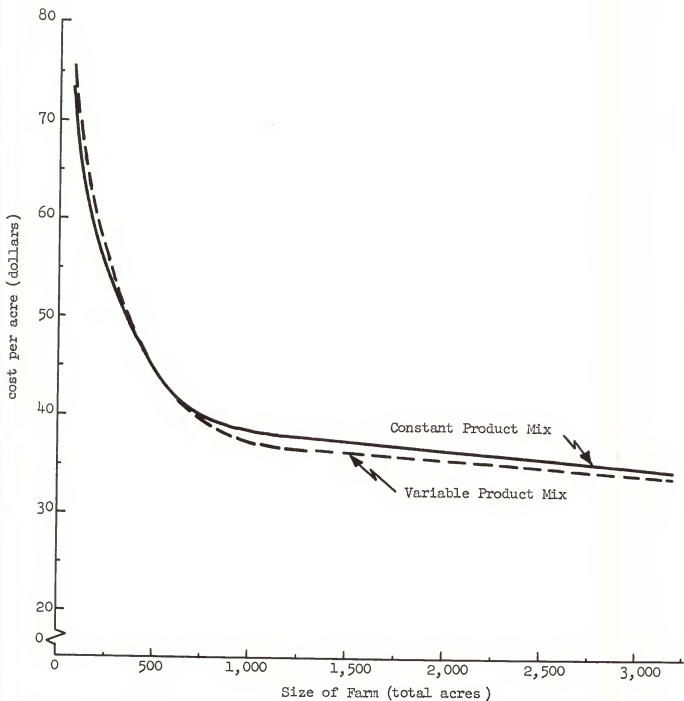
Source: Table 14.

FIGURE 10. Technical Economies Associated with Machinery,
Constant and Variable Product Mix,
Cotton-Alfalfa-Potato Farms



Source: Table 14.

FIGURE 11. Technical Economies Associated with Machinery, Constant and Variable Product Mix, Cotton-Alfalfa-Barley (dc) - Milo (dc)



Source: Table 14.

\$4.00 per acre higher, this would result in an increase of \$12,800 in annual total costs. This sum is a rather significant figure when it is considered as net revenue.

Investment in Machinery

The total and per acre investments for the 32 farming units are also presented in Table 1⁴. The investment in machinery, based on 1962 prices for new machinery, is approximately \$350,000 for the 3,200-acre farming units.^{1/} Of course, it would be unlikely that any farm unit would have purchased all new machinery. However, these figures serve as a guide in establishing the relative investment costs in machinery. The per acre investment in machinery for the 80-acre farming units is approximately two times that of the 3,200-acre farms. The per acre investment in machinery decreases most rapidly as the size of the smaller farms is increased. However, the decrease in per acre machinery investment is still quite large (ten percent or more) as the size of farm increases from 1,280 acres to 3,200 acres.

Why Technical Economies Associated with Machinery Occur

There are three major factors that are primarily responsible for technical economies associated with machinery. These are (1) annual use, (2) rate of accomplishment, and (3) machinery prices.

The cost per acre decreases as the annual use of a particular machine or machinery component increases. The decrease in per acre costs is quite rapid as the annual use is increased from a very small number of hours of annual use. However, the decrease in per acre costs becomes less and less as the hours of annual use increases and the per acre costs tend to "level off."

As farm size increases the acres of each operation to be performed also increases. Machinery with high rates of accomplishment (more expensive machinery) can then be economically justified. The cost per acre for these machines also decreases as annual use is increased. Finally, a point is reached when the largest machine for a particular operation is used to capacity during some restricting time period. Then multiples of these machines or smaller machines must be used. When multiples of the largest machines become necessary then most of the technical economies associated with machinery have been obtained.

^{1/} These are based on new costs. The investment figures used in Table 1² are one-half of those presented in Table 1⁴. The figures in Table 1² are based on machinery that is one-half depreciated.

Some additional economies may be obtained because there are a number of relatively inexpensive pieces of machinery, e.g., a ditcher, that may not be used to capacity in any time period. The reduction in costs due to increased annual use for these machines or implements will be rather small.

Machinery prices and labor costs are important in determining the magnitude of the technical economies associated with machinery. As the cost of a machine (or labor) increases, the annual cost per acre curve shifts upward and to the right. Thus, the dollar value of the decrease in costs for any given change (increase) in output, from a specified level, will be greater.

If prices paid for machinery increase in the future and if rates of accomplishment increase in the future, then the technical economies associated with machinery will become even greater (in terms of dollar costs per acre) as the size of the farm unit increases. If this occurs, the technical economies curves presented in Figures 9 through 11 would be expected to shift upward and to the right.

SUMMARY AND CONCLUSIONS

Physical rates of accomplishment for machines commonly used in the production of field crops in the Southern San Joaquin Valley are determined using the economic-engineering method. This method or technique is essentially that of specifying each component part of an operation performed by a machine or machines and the time and inputs required to perform the component parts of the operation. The component parts are then put together and expressed in terms of (1) field operation rates of accomplishment, and (2) field and nonfield operation rates of accomplishment. Field operation rates of accomplishment are based upon the time that machinery is in the field ready for operation. Field and nonfield operation rates of accomplishment take into account other losses in time such as going to and from fields, lubrication time, major breakdowns, etc. Both of the measures of rates of accomplishment are expressed in terms of acres or tons per hour.

The physical rates of accomplishment are costed using the 1962 price level. Farm records and other secondary data are quite heavily relied upon for this information. Special attention is given to repairs and the relationship between expected life and use in the costing of machinery.

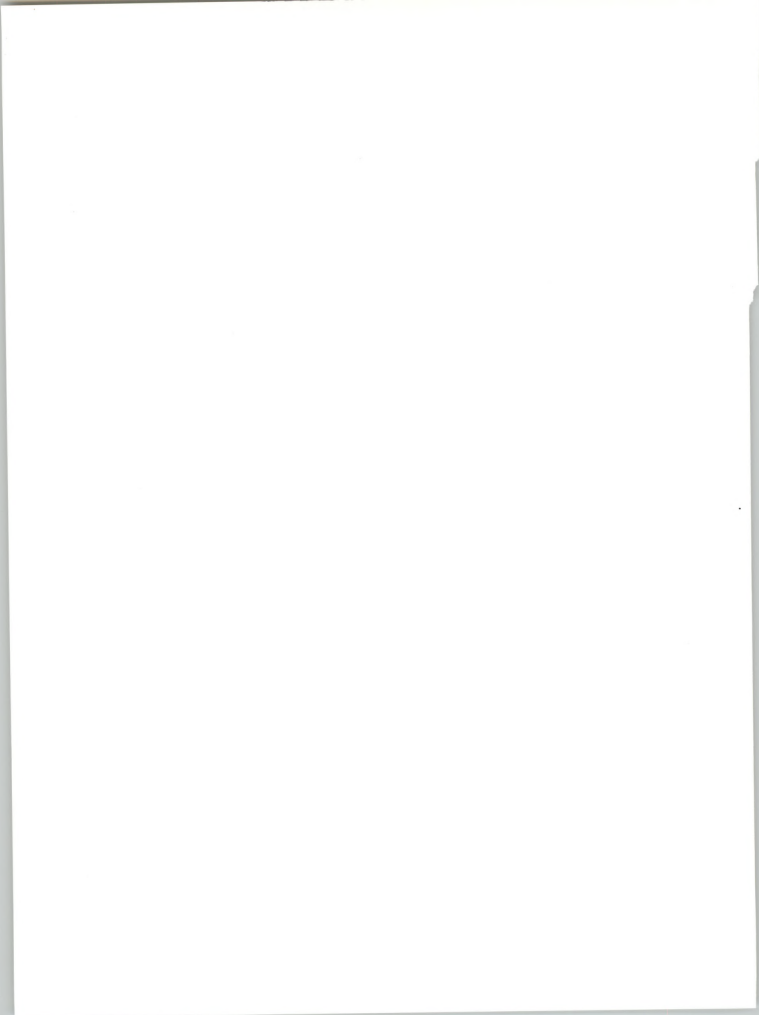
Least-cost machinery combinations for six farm sizes are selected. These are selected under specified conditions with respect to crops produced and hours available for work by time periods within the year. In the selection of the least-cost machinery combination, the hours of annual use of a machine is an important consideration. This is because the cost per hour decreases as the hours of annual use increases for a particular machine. In determining the size of machine to use, the cost per acre is an important consideration. As the size of the machine increases, and hence the rate of accomplishment, the labor cost per acre decreases. These two relationships are presented in graphs for the major operations or types of machines considered in this report. A comparison is also made with the cost of having these operations performed on a custom basis.

Linear programming is used to help select the least-cost machinery combinations for the six farm sizes. Three cropping programs are specified for each farm size. In addition, the cropping programs are investigated under the condition of a constant product mix and a variable product mix. The percent that each crop is of total cropland remains constant over all farm sizes under the

condition of a constant product mix. The variable product mix permits this percentage to vary. The variable product mix is typical of cotton farms in the Southern San Joaquin Valley as the smaller farm units have a greater percentage of total cropland planted in cotton than do the larger farm units. These 36 least-cost machinery combinations indicate that the cropping programs and product mixes investigated have little effect upon the least-cost machinery combinations with the exception of the more expensive specialized harvesting machines. Size of farm is the important factor in determining the size, type, and number of machines.

The least-cost machinery combinations are compared with machinery combinations "currently on" or "typical of" cotton farms in Kern County. The typical machinery combinations include a large excess of wheel tractors over that required to perform the necessary operations. The typical farms include a one-row cotton harvester on the 80-acre unit and a combine on the 640-acre unit when it would be less expensive to have these harvesting operations performed on a custom basis. However, the larger typical farms have their hay custom baled when it would be less expensive for these farms to own a baler and a hay swather. The typical investment in machinery is higher for all farm sizes than the least-cost machinery investment. The typical annual machinery cost ranges from \$14.00 per acre higher for the 80-acre farm unit to \$4.00 per acre higher for the 320-acre farm unit than the annual cost for least-cost machinery combinations. These are total costs, including labor, associated with the machinery operations.

Curves indicating the technical economies associated with machinery are constructed. The curves are based on the least-cost machinery combinations. The annual machinery costs per acre for the 80-acre farm units are more than double the annual costs for the 3,200-acre farm units. The reduction in costs amounts to \$40.00 or more per acre. However, most of the technical economies associated with machinery are obtained by the 1,280-acre farm units. In fact, more than 80 percent of the \$40.00 or more reduction in costs is obtained by the 640-acre farm units. Thus, it appears that there is a pressure (exerted by the possibility of reducing machinery costs) to increase the size of the farming operation. If this pressure can be measured in terms of the possible cost reduction, then it can be concluded that this pressure becomes considerably less after a farm size of 640 acres is obtained.



APPENDIX TABLES

APPENDIX TABLE 1

Performance and Cost Data per Hour for Tillage, Planting, Harvesting, and Miscellaneous Implements Used in the Production of Field Crops

Implement	Size of implement	Estimated cost 1962 dollars	Men re- quired ^a	Size of tractor ^b	Speed MPH	Acres per hour ^c	Average total costs per hour by hours of annual use ^d								Variable cost per hour ^e
							100	200	300	400	500	600	800	1,000	
							dollars								
Tillage Machines															
Chisel	6'	650	1	W-55, W-70	3.0	1.8	.98	.65	.57	.53	.50	.45	.42	.41	.22
"	8'	700	1	C-55	3.0	2.5	1.04	.68	.60	.55	.52	.47	.44	.42	.22
"	10'	800	1	C-80	3.0	3.0	1.15	.76	.65	.60	.57	.51	.47	.46	.22
"	12'	900	1	C-120	3.0	3.8	1.33	.88	.76	.72	.67	.60	.56	.55	.28
"	14'	1,000	1	C-180	3.0	4.4	1.61	1.05	.91	.85	.80	.72	.67	.65	.32
Cultipack	8'	560	1	W-35	6.0	4.6	.74	.47	.39	.36	.34	.29	.27	.26	.09
"	10'	840	1	W-35	6.0	5.8	1.10	.68	.57	.52	.48	.42	.38	.37	.12
Cultivate - first	2 row	350	1	W-25	2.5	1.7	.44	.36	.32	.30	.28	.26	.24	.24	.13
" - second	2 row		1	W-25	3.0	1.9									
" - other	2 row		1	W-25	5.3	3.1									
Cultivate - first	4 row	800	1	W-25	2.5	3.4	1.21	.82	.71	.66	.63	.57	.53	.52	.28
" - second	4 row		1	W-25	3.0	3.8									
" - other	4 row		1	W-25	5.3	6.1									
Cultivate - first	6 row	1,350	1	W-35	2.5	4.9	1.65	1.18	1.07	1.03	.98	.90	.85	.84	.48
" - second	6 row		1	W-35	3.0	5.8									
" - other	6 row		1	W-35	5.3	9.2									
Cultivate with fer- tilizer attachment	2 row	450	2	W-25	3.5	1.5	1.51	1.44	1.40	1.38	1.35	1.33	1.31	1.29	1.17
"	4 row	980	2	W-25	3.5	3.2	2.39	1.96	1.84	1.78	1.75	1.68	1.64	1.63	1.36
"	6 row	1,610	2	W-35	3.5	4.8	5.30	2.38	2.26	2.22	2.17	2.06	2.01	2.00	1.57
Disk, border ^f / " "	single tandem	325 600	1 1	W-25 W-35	3.3 3.3	5.9 5.9	.88 1.59	.55 .99	.44 .79	.40 .71	.37 .65	.35 .62	.32 .57	.31 .55	.12 .19
Disk, harrow (offset)	4'	525	1	W-25	3.3	1.2	.76	.50	.43	.40	.38	.34	.31	.30	.15
" " "	6-3/4'	900	1	W-35	3.3	2.0	1.31	.86	.74	.69	.65	.58	.54	.53	.26
" " "	9'	1,200	1	W-45	3.3	2.6	1.74	1.14	.98	.92	.86	.77	.72	.70	.34
" " "	9-3/4'	1,300	1	W-55	3.3	2.9	1.89	1.24	1.07	1.00	.89	.84	.78	.76	.37
" " "	10-1/2'	1,500	1	W-70	3.3	3.1	2.18	1.43	1.24	1.15	1.08	.97	.90	.88	.43
" " "	12'	1,750	1	C-55	3.3	3.5	2.55	1.67	1.44	1.35	1.26	1.13	1.05	1.03	.50
" " "	13-1/2'	2,000	1	C-55	3.3	4.0	2.90	1.91	1.64	1.53	1.44	1.29	1.20	1.17	.57
" " "	15'	2,350	1	C-80	3.3	4.4	3.42	2.24	1.93	1.80	1.58	1.52	1.41	1.37	.67
" " "	18'	2,700	1	C-80	3.3	5.3	3.92	2.57	2.22	2.07	1.94	1.75	1.61	1.58	.77
" " "	21'	3,600	1	C-120	3.3	6.2	5.23	3.43	2.96	2.77	2.59	2.33	2.16	2.11	1.03
" " "	24'	3,800	1	C-120	3.3	7.1	5.52	3.62	3.13	2.92	2.74	2.46	2.28	2.23	1.09
" " "	28'	4,400	1	C-150	3.3	8.2	6.38	4.19	3.61	3.37	3.16	2.84	2.62	2.57	1.25
Disk, harrow (tandem)	6'	575	1	W-25, W-35	3.3	1.8	.86	.58	.50	.47	.44	.40	.37	.36	.19
" " "	8'	600	1	W-45	3.3	2.4	.90	.60	.52	.49	.46	.42	.40	.38	.20
" " "	10'	750	1	W-55	3.3	2.9	1.12	.94	.84	.80	.76	.71	.68	.66	.24
" " "	12'	925	1	W-70	3.3	3.5	1.37	.90	.75	.73	.69	.62	.58	.57	.29

(Continued on next page.)

APPENDIX TABLE 1 continued.

Implement	Size of implement	Estimated cost 1962 dollars	Men required ^a	Size of tractor ^b	Speed MPH	Acres per hour ^c	Average total costs per hour by hours of annual use ^d								Variable cost per hour ϵ	
							dollars									
							100	200	300	400	500	600	800	1,000		
Ditcher	4'	350	1	W-25		8.0	.46	.29	.24	.22	.20	.18	.16	.15		.05
Drag	12'	60	1	W-35	4.5	5.9	.09	.06	.05	.05	.05	.04	.04	.04		.02
Flame weeder	2 row	550	1	W-25	3.0	1.7	.95	.60	.51	.48	.45	.44	.41	.38		.21
" "	4 row	750	1	W-25	3.0	3.8	1.27	.80	.67	.63	.60	.58	.55	.50		.27
" "	6 row	950	1	W-35	3.0	5.6	1.61	1.01	.85	.80	.75	.74	.70	.63		.34
Harrow, spike	4'	100	1	W-25	4.5	1.7	.13	.08	.06	.06	.05	.05	.04	.04		.01
" "	8'	200	1	W-25	4.5	3.4	.25	.15	.13	.12	.11	.09	.08	.08		.02
" "	12'	300	1	W-25	4.5	5.1	.38	.23	.19	.17	.16	.14	.12	.12		.03
" "	16'	400	1	W-35	4.5	6.8	.51	.31	.26	.23	.21	.18	.16	.16		.04
" "	20'	500	1	W-45	4.5	8.5	.64	.39	.32	.29	.27	.23	.21	.20		.05
" "	24'	600	1	W-55	4.5	10.2	.76	.46	.38	.35	.32	.28	.25	.24		.06
" "	28'	700	1	W-70	4.5	11.9	.89	.54	.45	.41	.37	.32	.29	.28		.07
" "	32'	800	1	C-55	4.5	13.6	1.02	.62	.51	.46	.42	.37	.33	.32		.08
" "	40'	1,000	1	C-80	4.5	17.1	1.27	.77	.64	.58	.53	.46	.41	.40		.10
Harrow, spring tooth ^e	8'	400	1	W-25	4.5	3.4	.53	.32	.27	.25	.23	.20	.18	.18		.06
" "	12'	750	1	W-25	4.5	5.1	.97	.59	.49	.45	.41	.36	.32	.32		.09
" "	16'	900	1	W-35	4.5	6.8	1.16	.71	.59	.55	.50	.43	.39	.38		.11
" "	20'	1,050	1	W-45	4.5	8.5	1.36	.84	.70	.64	.59	.52	.47	.45		.14
" "	24'	1,200	1	W-70, C-55	4.5	10.2	1.57	.97	.81	.75	.69	.60	.55	.53		.17
Landplane	8'x30'	2,400	1	W-55, W-70	3.5	2.5	3.15	1.95	1.64	1.51	1.39	1.22	1.10	1.07		.35
" "	10'x40'	2,840	1	C-55	3.5	3.2	3.71	2.30	1.93	1.77	1.63	1.42	1.29	1.25		.40
" "	12'x50'	3,570	1	C-80	3.5	3.8	4.66	2.88	2.42	2.22	2.05	1.79	1.62	1.57		.50
" "	15'x80'	4,600	1	C-120	3.5	4.7	6.02	3.71	3.12	2.87	2.64	2.31	2.09	2.03		.65
Lister	2 row	400	1	W-35	3.5	2.4	.66	.49	.40	.38	.36	.33	.31	.31		.19
" "	4 row	850	1	W-70, C-55	3.5	4.8	1.28	.85	.74	.69	.65	.59	.55	.53		.28
Plow, disk ^f	3 disk	1,187	1	W-35	3.5	1.4	2.03	1.44	1.29	1.22	1.16	1.08	1.02	1.01		.65
" "	4 disk	1,300	1	W-45	3.5	1.9	2.24	1.58	1.40	1.33	1.27	1.18	1.12	1.10		.72
" "	4 disk	1,450	1	W-55, W-70	3.5	2.4	2.49	1.76	1.58	1.50	1.43	1.32	1.25	1.23		.80
" "	6 disk	1,506	1	C-55	3.5	2.9	2.58	1.83	1.64	1.55	1.48	1.37	1.30	1.28		.83
" "	7 disk	1,685	1	C-80	3.5	3.4	2.88	2.04	1.82	1.73	1.65	1.53	1.45	1.42		.92
Plow, 2-way mold board	2-12"	400	1	W-25	2.5	.8	.69	.48	.43	.41	.39	.36	.34	.34		.22
" "	2-14"	525	1	W-35	2.5	1.1	.91	.65	.58	.55	.53	.49	.46	.46		.30
" "	2-16"	675	1	W-45	2.5	1.2	1.15	.81	.72	.65	.62	.60	.57	.56		.36
" "	3-16"	850	1	W-55, W-70	2.5	1.9	1.45	.97	.86	.81	.77	.71	.67	.65		.45
" "	4-16"	1,030	1	C-55	2.5	2.5	1.73	1.22	1.08	1.03	.98	.90	.85	.84		.53
" "	5-16"	1,213	1	C-80	2.5	3.1	2.08	1.47	1.31	1.24	1.19	1.10	1.04	1.02		.66
Scraper	10'	500	1	W-35	--	8.0	.69	.45	.38	.35	.33	.29	.27	.25		.11

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APPENDIX TABLE 1 continued.

Implement	Size of implement	Estimated cost 1962 dollars	Men re-quired ^a	Size of tractor ^b	Speed MPH	Acres per hour ^c	Average total costs per hour by hours of annual use ^d / dollars									Variable cost per hour ^e
							100	200	300	400	500	600	800	1,000		
Subsoiler	4'	1,000	1	W-55, W-70	2.2	1.0	1.32	.81	.69	.63	.58	.51	.46	.45	.15	
"	6'	1,500	1	C-55	2.2	1.4	1.98	1.23	1.04	.95	.88	.77	.70	.68	.23	
"	8'	2,000	1	C-80	2.2	1.9	2.63	1.64	1.37	1.26	1.17	1.02	.92	.90	.30	
"	10'	2,500	1	C-120	2.2	2.3	3.29	2.03	1.71	1.57	1.45	1.27	1.15	1.12	.37	
"	12'	3,000	1	C-180	2.2	2.7	3.95	2.45	2.06	1.90	1.75	1.53	1.39	1.35	.45	
Thinner	2 row	350	1	W-25	3.0	1.9	.53	.36	.31	.29	.27	.25	.23	.23	.12	
"	4 row	500	1	W-25	3.0	3.8	.74	.50	.43	.40	.38	.34	.32	.31	.16	
"	6 row	700	1	W-35	3.0	5.8	1.04	.68	.60	.56	.52	.47	.44	.43	.22	
Planting Machines																
Broadcaster ^f	100#	70	1	W-25	--g/	1.0	.21	.15	.12	.11	.11	.10	.09	.09	.05	
"	1,500#	275	1	W-25	--	1.5	.68	.49	.40	.36	.33	.32	.29	.29	.12	
Grain drills	10'	900	2	W-25	4.0	3.3	2.09	1.49	1.12	1.07	.99	.94	.85	.83	.29	
"	12'	1,000	2	W-25	4.0	3.8	2.30	1.63	1.30	1.18	1.07	1.02	.92	.90	.30	
"	14'	1,150	2	W-25	4.0	4.2	2.67	1.90	1.51	1.37	1.25	1.19	1.08	1.05	.36	
Planters, row	2 row	400	2	W-25	4.5	1.6	.94	.67	.54	.49	.45	.43	.39	.38	.14	
"	4 row	700	2	W-25	4.5	4.4	1.62	1.15	.92	.83	.76	.73	.66	.64	.22	
"	6 row	1,150	2	W-35	4.5	6.2	2.67	1.90	1.51	1.37	1.25	1.19	1.08	1.05	.36	
Potato planter ^h	2 row	550	1 or 2	W-35	3.5	1.6	1.29	.91	.72	.65	.60	.57	.51	.50	.17	
"	4 row	950	2 or 4	C-55	3.5	2.2	2.20	1.55	1.23	1.12	1.02	.97	.88	.85	.28	
Harvesting Machines																
Bale loader, automatic		7,900	2	SP	8-10	9.9T	14.40	11.11	8.11	7.68	7.29	7.16	6.80	6.24	3.37	
Bale loader, truck ⁱ		450	1	truck	--h/	3.3T	.88	.50	.40	.37	.34	.33	.30	.26	.08	
Baler, with motor	3 wire	5,400	1	W-35	4.0	8.0T	15.57	12.17	11.27	10.97	10.71	10.62	10.39	9.99	8.37	
Baler, PTO	2 wire	3,100	1	W-35	4.0	5.2T	9.08	7.13	6.61	6.45	6.29	6.24	6.11	5.88	4.95	
Baler, SP	3 wire	8,000	1	SP	4.0	9.0T	21.76	17.04	15.76	15.33	14.96	14.83	14.51	13.96	11.76	
Bean cutter ^f	2 row	200	1	W-25	3.5	1.9	.38	.25	.22	.21	.20	.19	.18	.17	.11	
"	4 row	400	1	W-25	3.5	3.9	.66	.41	.34	.32	.30	.30	.28	.25	.13	
"	6 row	450	1	W-35	3.5	6.0	.88	.54	.46	.44	.41	.40	.39	.35	.22	
Beet harvester ^f	1 row	3,850	1	W-45	--	.3	6.13	3.71	3.07	2.86	2.67	2.60	2.44	2.15	1.00	
Combine, SP	12'	9,000	1	SP	2.0	2.3	15.41	9.75	8.24	7.75	7.31	7.16	6.79	6.11	3.41	
"	14'	11,000	1	SP	2.0	2.8	18.72	11.80	9.96	9.35	8.82	8.63	8.17	7.35	4.05	
Cotton picker, pull	1 row	9,000	1	W-35	2.5	.7	15.41	9.75	8.24	7.75	7.31	7.16	6.79	6.11	3.41	
"	2 row	20,000	1	SP	2.5	1.5	33.60	21.02	17.67	16.57	15.60	15.26	14.42	12.93	6.93	

(Continued on next page.)

APPENDIX TABLE 1 continued.

Implement	Size of implement	Estimated cost 1962 dollars	Men re- quired ^{a/}	Size of tractor ^{b/} dollars	Speed MPH	Acres per hour ^{c/}	Average total costs per hour by hours of annual use ^{d/}										Variable cost per hour ^{e/}
							100	200	300	400	500	600	800	1,000			
							dollars										
Hay conditioner	7'	1,000	1	W-25	4.5	2.8	1.76	1.13	.97	.91	.86	.85	.81	.73	.43		
Mower	7'	500	1	W-25	5.0	3.2	.99	.64	.55	.52	.49	.48	.46	.42	.25		
Potato digger	1 row	600	2	W-35	2.5	.4	2.25	1.87	1.77	1.74	1.71	1.70	1.67	1.63	.20		
	2 row	1,000	2	W-55	2.5	1.0	2.91	2.28	2.12	2.06	2.01	2.00	1.96	1.88	.33		
Potato harvester	2 row	14,000	8	C-55	2.5	1.2	40.40	27.80	26.75	25.60	25.40	25.30	--	--	15.15		
Rake, side delivery	8'	750	1	W-25	4.8	3.8	1.21	.74	.61	.57	.53	.52	.49	.44	.20		
Rake, wheel	8'	700	1	W-25	4.8	3.8	1.13	.70	.58	.54	.50	.49	.46	.41	.20		
Swather	12'	5,000	1	SP	3.8	3.5	8.67	5.52	4.69	4.41	4.17	4.08	3.88	3.50	2.00		
"	14'	5,300	1	SP	3.8	4.0	8.97	5.79	4.90	4.61	4.35	4.26	4.04	3.64	2.05		
"	16'	5,600	1	SP	3.8	4.6	9.57	6.04	5.11	4.80	4.53	4.43	4.20	3.78	2.10		
Trailers, cotton	4 bale	400	1	truck		.7	.67	.42	.35	.33	.31	.30	.29	.26	.14		
"	5 bale	450	1	truck		.7	.75	.47	.39	.37	.34	.33	.32	.28	.15		
"	6 bale	500	1	truck		.7	.84	.52	.44	.41	.39	.38	.36	.32	.17		
Miscellaneous																	
Duster	6 row	300	1	W-25	5.0		.47	.28	.23	.21	.20	.19	.18	.16	.07		
Fertilizer spreader	8'	300	1	W-25	4.0	3.0	.47	.28	.23	.21	.20	.19	.18	.16	.07		
"	10'	370	1	W-25	4.0	3.5	.57	.34	.28	.26	.24	.23	.22	.19	.08		
"	12'	450	1	W-25	4.0	3.9	.71	.43	.37	.33	.31	.30	.28	.24	.11		
Sprayer, weed ^{f/}	200 gal	800	1	W-25	4.0	5.1	1.78	1.27	1.14	1.09	1.06	1.04	1.01	.95	.71		
Stalk cutter	2 row	350	1	W-35	3.5	2.2	.61	.39	.33	.31	.29	.29	.27	.25	.14		
Tool bar	9'	1,500					2.13	1.38	1.19	1.10	1.03	.92	.85	.83	.38		
"	12'	2,000					2.83	1.84	1.57	1.46	1.37	1.22	1.12	1.10	.50		
Tool carrier		750					1.02	.64	.54	.50	.47	.41	.38	.37	.14		
"		1,000					1.32	.81	.69	.63	.58	.51	.46	.45	.15		
Trailer, flatbed		1,400					1.83	1.14	.95	.88	.81	.70	.64	.62	.20		

a/ This includes the total number of men required for the operation. The one man needed for most operations is the tractor driver.

b/ Smallest tractor normally used for that size implement.

c/ This refers to rates of accomplishment for uninterrupted operation. Included are losses of time due to overlap, turnaround, filling planters or spreaders, unloading harvesters, and normal delays for adjustment of machinery. For a 12-hour day the daily rate of accomplishment can be approximated by multiplying acre per hour x 10. Approximately 2 hours per day are lost because of breakdowns, lunch, getting to and from the field, etc.

d/ Does not include tractor or driver charges. The exception is self-propelled equipment which does include all cost.

e/ Variable costs include fuel, lubrication, and repair costs. Labor costs are also included for self-propelled machines.

f/ Cost taken from: A. D. Reed, Machinery Costs and Related Data, University of California Extension Service, May 1959 (unpublished).

The Assist-Feed Potato Planters require twice the workers compared to the picker-type planter. Costs are based on the picker-planter.

h/ Data not available.

APPENDIX TABLE 2

Repair and Maintenance Rates per Year as a Percent
of New Cost by Hours of Annual Use a/

Machine	Hours of annual use								
	100	150	200	250	300	400	600	800	1,000
	percent								
<u>Tractors^{b/}</u>									
Wheel	2.8	3.2	3.6	4.0	4.4	5.1	6.7	8.2	9.8
Crawler	2.8	3.1	3.5	3.8	4.3	5.0	6.5	8.0	9.5
<u>Tillage machines</u>									
Chisel	2.9	4.3	5.7	7.6	8.6	11.4	17.2	22.9	28.6
Cultipacker	1.0	1.5	2.0	2.6	3.0	4.0	6.0	8.0	10.0
Cultivator, w/fert. att'h.	2.9	4.3	5.7	7.6	8.6	11.4	17.2	22.9	28.6
Cultivator, w/o fert. att'h.	3.2	5.0	6.4	8.1	9.6	13.0	19.4	26.0	32.3
Disk harrow offset	2.9	4.3	5.7	7.6	8.6	11.4	17.2	22.9	28.6
Disk harrow, tandem	2.9	4.3	5.7	7.6	8.6	11.4	17.2	22.9	28.6
Ditcher	2.1	3.1	4.1	5.5	6.2	8.2	12.3	16.5	20.6
Drag	1.0	1.5	2.0	2.5	3.0	4.0	6.0	8.0	10.0
Flame weeder	3.0	4.5	6.0	6.8	9.0	12.0	18.0	24.0	30.0
Harrow, spike	1.4	2.0	2.7	3.4	4.0	5.3	8.0	10.7	13.3
Harrow, spring	1.4	2.0	2.7	3.4	4.0	5.3	8.0	10.7	13.3
Landplane	1.6	2.4	3.2	4.0	4.8	6.4	9.6	12.8	16.0
Lister	4.0	6.0	8.0	10.0	12.0	16.0	24.0	32.0	40.0
Plow, disk	5.5	8.2	11.0	13.8	16.5	22.0	33.0	44.0	55.0
Plow, mold board	5.5	8.2	11.0	13.8	16.5	22.0	33.0	44.0	55.0
Border disk	3.1	4.6	6.2	7.8	9.3	12.4	18.6	24.8	31.0
Scraper	2.1	3.2	4.2	5.2	6.3	8.4	12.6	16.8	21.0
Subsoiler	1.6	2.4	3.2	4.0	4.8	6.4	9.6	12.8	16.0
Thinner	1.5	2.3	3.1	4.1	4.6	6.1	9.2	12.3	15.3
<u>Planting machines</u>									
Broadcaster	4.5	6.8	9.0	11.2	13.5	18.0	27.0	36.0	45.0
Grain drills	2.4	3.6	4.8	6.0	7.2	9.6	14.4	19.2	24.0
Planter, row	2.9	4.4	5.8	7.2	8.7	11.6	17.4	23.2	29.0
Planter, potato	2.9	4.4	5.8	7.2	8.7	11.6	17.4	23.2	29.0
<u>Harvesting machines^{b/}</u>									
Beet loader	1.4	2.1	2.8	3.5	4.2	5.6	8.4	11.2	14.0
Baler, vire w/motor	4.0	5.0	6.0	7.0	8.0	10.0	14.0	18.0	22.0
Baler, PTO	4.0	5.0	6.0	7.0	8.0	10.0	14.0	18.0	22.0
Baler, SP	4.0	5.0	6.0	7.0	8.0	10.0	14.0	18.0	22.0
Bankout wagon	2.0	3.0	4.0	5.0	6.0	8.0	12.0	16.0	20.0
Bean cutter	4.0	6.0	8.0	10.0	12.0	16.0	24.0	32.0	40.0
Beet harvester	3.9	5.4	6.8	8.2	9.7	12.6	18.4	24.2	30.0
Combine, SP	4.6	5.9	7.2	8.5	9.8	12.4	17.6	22.8	28.0
Cotton picker, mounted ^{c/}	4.6	5.9	7.2	8.5	9.8	12.4	17.6	22.8	28.0
Cotton picker, SP	4.9	6.4	7.8	9.2	10.7	13.6	19.4	25.2	31.0
Potato digger	2.5	3.8	5.0	6.2	7.5	10.0	15.0	20.0	25.0
Potato harvester	4.6	5.9	7.2	8.5	9.8	12.4	17.6	22.8	28.0
Rake	3.0	4.5	6.0	7.5	9.0	12.0	18.0	24.0	30.0
Swather, SP	5.7	7.6	9.4	11.2	13.1	16.8	24.2	31.6	39.0
Cotton trailer	1.8	2.7	3.6	4.5	5.4	7.2	10.8	14.4	18.0
Mower	4.0	6.0	8.0	10.0	12.0	16.0	24.0	32.0	40.0
<u>Misc. machines</u>									
Duster	2.1	3.2	4.2	5.2	6.3	8.4	12.6	16.8	21.0
Fertilizer spreader	4.5	6.8	9.0	11.2	13.5	18.0	27.0	36.0	45.0
Sprayer	4.7	6.0	7.4	8.8	10.1	12.8	18.2	23.6	29.0
Stalk cutter	4.0	6.0	8.0	10.0	12.0	16.0	24.0	32.0	40.0

a/ Repairs and maintenance are based on the percentage of new cost. Based on the findings of this study, repairs and maintenance are directly related to use. Therefore once an hourly rate is calculated this figure can be applied to the machine regardless of annual use.

b/ The exceptions to footnote "a" are tractors and power equipment. In addition to a constant hourly rate, two percent of the new cost is charged as fixed repair cost per year.

c/ Does not include tractor.

Source: From individual farm records in the study and from various machinery and equipment studies including repair and maintenance data.

APPENDIX TABLE 3

Investment, Total, and Variable Cost for Wheel and Crawler Tractors,
1/2 Ton and 1-1/2 Ton Farm Trucks

Item	Size DBH ^a /	Approx. new cost 1961	Total cost per hour ^b						Heavy duty variable cost ^c	Light duty variable cost ^d
			Hours per year							
			200	600	1,000	1,400	1,800	2,200		
dollars										
<u>Tractors</u>										
Wheel gasoline										
W-25	25	3,100	4.24	3.03	2.77	2.70	2.66	2.63	2.29	2.14
W-35	35	3,750	4.82	3.35	3.05	2.96	2.90	2.87	2.46	2.24
W-45	45	5,000	5.84	3.90	3.49	3.37	3.30	3.25	2.71	2.44
W-55	55	6,250	6.85	4.41	3.90	3.76	3.67	3.61	2.90	2.65
W-70	70	7,500	7.86	4.96	4.36	4.18	4.08	3.94	3.19	2.94
<u>Crawler Diesel</u>										
C-55	55	10,000	9.15	5.28	4.44	4.21	4.07	3.97	2.89	2.70
C-80	80	16,000	13.49	7.27	5.96	5.60	5.37	5.21	3.48	3.15
C-120	120	21,000	17.28	9.12	7.41	6.93	6.63	6.43	4.15	3.72
C-180	180	34,000	25.70	12.48	9.71	8.94	8.46	8.12	6.16	5.30

Item	Size DBH ^a /	Approx. new cost	Estimated average cost per mile						Variable cost per mile ^e	Hourly rate 20,000 mile per year ^f
			Miles per year							
			5,000	10,000	15,000	20,000	25,000	30,000		
<u>Pick-up</u>										
3-year life	1 1/2 T	2,100	.16	.098	.078	.068	.063	.060	.036	2.04
5-year life	1 1/2 T	2,100	.145	.091	.074	.065	--	--	.039	1.96
<u>Trucks</u>										
3-year life	1-1/2 T	2,900	.522	.28	.208	.174	.147	.142	.07	4.16
5-year life	1-1/2 T	2,900	.380	.228	.174	.150	.134	.127	.08	3.48

^a Based on maximum drawbar horsepower. Not 75 percent of maximum drawbar horsepower. See Nebraska Tractor Test, 1961.^b Calculated at 75 percent maximum pull.^c Calculated at 50 percent maximum pull.^d It has been suggested that an hourly rate can be approximated by assuming 30 miles per hour for pick-ups and 20 miles for larger trucks. Does not include charge for operator.^e Does not include a charge for operator.Source: Tractor cost for study data. Truck cost from Capstick, D. F., Cost of Owning and Operating Farm Trucks in Eastern Arkansas, Bulletin 639. Agricultural Experiment Station, Fayetteville, Arkansas, April 1961.

APPENDIX TABLE 4

Number and Annual Cost of Automotive Equipment
Typically Found on Farms
in the Study Area

Invest- Annual ment cost			Size of farm (total acres)											
			80		160		320		640		1,280		3,200	
			Number	Annual cost	Number	Annual cost	Number	Annual cost	Number	Annual cost	Number	Annual cost	Number	Annual cost
Item	dollars			dollars		dollars		dollars		dollars		dollars		dollars
Pick-ups, 1/2 T	2,100	600	1	600	1	600	1	600	2	1,200	3	1,800	6	3,600
1 1/2 ton truck	2,900	720					1	720	1	720	2	1,440	4	2,880
Trailer, flatbed	1,400	180			1	180	1	180	1	180	2	360	4	720
Trailer, utility	1,400	180							1	180	1	180	2	360
Implement Carryall (small)	750	75	1	75	1	75								
Implement Carryall (large)	1,000	100					1	100	1	100	1	100	2	200
Total				675		855		1,600		2,380		3,880		7,760
Ave. per acre				8.44		5.34		5.00		3.72		3.03		2.43

APPENDIX TABLE 5

Custom Rates per Acre

Operation	Custom rate per acre ^{a/} dollars
Pick cotton, 1,200 lb. lint/acre ^{b/}	50.00
Combining	6.00
Dig potatoes	12.00
Pick potatoes	48.00
Mechanical potato harvester, 300 sacks/acre	60.00
Light land preparation ^{c/}	3.90
Heavy land preparation ^{d/}	6.50
Baling	3.50/ton
Swather	2.00
Mowing	1.50
Raking	1.50
Cultivating	1.60
Misc. operations ^{e/}	1.80

^{a/} Does not include a charge for companion jobs such as hauling.

^{b/} Twice over; \$1.50 per pound of seed cotton with 35 percent lint yield (1,400 lbs. seed cotton = 490 lbs. lint = 1 bale).

^{c/} Includes disking \$1.75, chiseling \$5.00, plowing \$4.00. The average rate is weighted by the time normally required for each operation and not a simple average.

^{d/} Includes subsoiling \$8.00, landplaning \$5.00.

^{e/} This group of operations includes: furrowing out, making borders, broadcasting, harrowing, planting, cultipacking, etc., charges run from \$1.00 to \$2.00 per acre.

APPENDIX TABLE 6

Rental Rates, as a Percent of New Retail Delivered Price^{a/}

Length of rental	Crawler tractors b/		Large wheel tractors c/		Small wheel tractors d/		Implements e/	
	Delivered ^{f/}	Not delivered	Delivered	Not delivered	Delivered	Not delivered	Delivered	Not delivered
One day (12 hrs.)	.4	.3	.6	.5	1.0	.7	2.0	1.5
One week	1.8	1.7	2.6	2.5	3.6	3.3	8.0	7.5
One month	5.1	5.0	7.6	7.5	10.3	10.0	23.0	22.5
Two months	8.4	8.3	12.6	12.5	17.0	16.7	38.0	37.5
Three months	11.2	11.1	16.6	16.5	22.5	22.2	50.0	49.7
Over three months	.93/wk.	.92/wk.	1.38/wk.	1.37/wk.	1.87/wk.	1.85/wk.	4.17/wk.	4.14/wk.

a/ These charges are for use of the machine only. Extras, such as operator, fuel, supplies would be added. In some cases there may be additional charges for wear on parts, e.g., plow shares, scraper blades.

b/ To estimate value of tractor, a wheel tractor (gas or diesel) will sell, complete, at approximately \$95 per horsepower. Crawler tractors' gas per horsepower and; crawler (diesel) \$215 per horsepower.

c/ 36 MAX DBHP or greater.

d/ 35 MAX DBHP or less.

e/ Implement refers to equipment without auxiliary engines or complex self-propelled harvesting equipment. Such equipment would fall under the heading of "large wheel tractors."

f/ Pick-up and return was estimated at 6 hours; labor \$1.25 per hour, truck \$1.50 per hour.

Source: Equipment dealers and rental establishments in the study area.

APPENDIX TABLE 7

Machinery Costs, Power Units, and Labor Associated with Machine Operations
by Size of Farm, Variable Product Mix, Cotton-Alfalfa Farms

Item	Acres	Power unit	Man-hours	Machine hours	Machine cost per unit	Size of farm (total acres)					Acres	Power unit	Man-hours	Machine hours	Machine cost per unit		
						Size of farm (total acres)											
						Size of farm (total acres)											
80						160						320					
dollars						dollars						dollars					
Crops																	
Cotton	35					64					120						
Alfalfa	40					86					180						
Total	75					150					300						
Operations																	
Pick cotton	70	Custom			25.00/ac	128	1-row picker	213	183	10.30/hr	240	1-row picker	400	312	8.05/hr		
Bale alfalfa	200	Custom			3.50/ac	602	V-35	94	75	18.50/hr	1,260	V-35	210	158	12.80/hr		
Light land preparation	200	V-35	250	200	.80/hr	395	V-35	481	395	.60/hr	710	V-35	315	50	1.05/hr		
Heavy land preparation	93	Custom			6.50/ac	107	Custom			6.50/ac	213	C-55	166	134	1.20/hr		
Bake alfalfa	280	V-35	109	87	1.13/hr	602	V-35	226	183	.60/hr	1,260	Swather	378	315	4.85/hr		
Rake alfalfa	280	V-35	85	74	1.30/hr	602	V-35	188	159	.46/hr	1,260	V-35	210	166	1.72		
Cultivate cotton	210	V-35	49	40	1.87/hr	394	V-35	89	74	1.53/hr	720	V-35	172	139	1.68/hr		
Haul cotton a/	70	Truck	193	100	1.75/hr	128	Truck	237	183	1.33/hr	240	Truck	444	343	.90/hr		
Misc. light operations	245	V-35	66	56	1.64/hr	448	V-35	121	102	1.57/hr	840	V-35	240	191	1.40/hr		
Total b/																	
Labor losses not associated with field operations			84					1,649	1,349				2,995	2,092			
Power equipment								224					320				
25 HP wheel tractor																	
35 HP wheel tractor	1			457	3.70/hr	1		1,166	2.75/hr		1		996	3.05/hr			
55 HP crawler tractor											1		434	5.35/hr			
80 HP crawler tractor																	
120 HP crawler tractor																	
Self-propelled swather											1		315	see now			
Self-propelled cotton picker																	
Self-propelled baler																	
Automotive equipment a/	80				8.44/ac	150				5.34/ac	320				5.00/ee		
640																	
1,280																	
3,200																	
dollars																	
Crops																	
Cotton	214					358					800						
Alfalfa	356					542					2,800						
Total	560					900					3,000						
Operations																	
Pick cotton	428	2-row picker	357	285	18.00/hr	716	2-row picker	597	477	13.00/hr	1,600	2-row picker	1,333	1,067	18.30/hr		
Bale alfalfa	2,702	SP baler	373	303	11.97/hr	5,694	SP baler	813	654	11.97/hr	15,400	SP baler	2,129	1,709	11.90/hr		
Light land preparation	1,435	C-80	592	435	1.10/hr	2,695	C-120	396	321	1.92/hr	6,500	C-120	956	774	1.48/hr		
Heavy land preparation	434	C-80	595	207	1.97/hr	871	C-120	256	207	.85/hr	2,186	C-120	1,029	4,300	1.93/hr		
Bake alfalfa	2,702	Swather	811	676	4.33/hr	5,694	Swather	721	716	.57/hr	15,400	Swather	4,620	3,850	4.09/hr		
Cultivate cotton	1,284	V-45	422	396	.58/hr	2,183	V-45	500	473	.61/hr	4,800	V-45	2,407	2,066	.60/hr		
Haul cotton a/	1,428	Truck	259	247	.87/hr	2,183	Truck	1,306	1,023	.75/hr	800	Truck	1,116	923	.88/hr		
Misc. light operations	1,495	V-45	405	304	1.38/hr	2,536	V-45	677	570	1.15/hr	5,600	V-45	1,422	1,113	.75/hr		
Total b/																	
Labor losses not associated with field operations			267	3,457				7,928	6,454				18,172	14,846			
Power equipment								997					2,513				
25 HP wheel tractor	1			943	2.80/hr	2		1,759	22.85/hr		4		4,222	2.80/hr			
35 HP wheel tractor																	
55 HP crawler tractor	1			642	7.15/hr	1		539	5.65/hr		2		1,300	5.10/hr			
80 HP crawler tractor																	
120 HP crawler tractor	1																
Self-propelled swather	1			676	see now	2		328	10.00/hr		2		1,955	8.05/hr			
Self-propelled cotton picker	1			285	see pick cotton	2		477	see pick cotton		5		1,890	see now			
Self-propelled baler	1			300	see bale	2		674	see bale		4		1,067	see pick cotton			
Automotive equipment a/	640				3.72/ee	1,280				3.03/ac	3,200		1,709	see to be	2.43/ac		

a/ The cost per hour includes only the cost of cotton tractors. The labor on this operation is usually supervisory in nature and truck cost is included with automotive equipment.

b/ Total man-hours required to keep machinery operating the designated hours. This includes multiple man operations as well as losses associated with nonfield operations.

c/ Man-hours lost in nonfield operations, e.g., to and from field, lunch, unusual delays from breakdown, etc.

d/ See Appendix Table 3.

Source: Tables 2, 4, 5 and Figures 5, 6, and 7.

Machinery Costs, Power Units, and Labor Associated with Machine Operations
by Size of Farm, Variable Product Mix, Cotton-Alfalfa-Potato Farms

a/ The cost per hour includes only the cost of cotton trailers. The labor on this operation is usually supervisory in nature and truck cost is included with automatic equipment.

b/ Total man-hours required to keep machinery operating the designated hours. This includes multiple man operations as well as losses associated with nonfield operations.

c/ Man-hours lost in nonfield operations, e.g., to and from field, lunch, unusual delays from breakdown, etc.

d/ See Appendix Table 3.

Source: Tables 2, 4, 5 and Figures 5, 6, and 7.

APPENDIX TABLE 9

Machinery Costs, Power Units, and Labor Associated with Machine Operations of Size of Farm, Variable Product Mix, Cotton-Alfalfa-Barley (ac), Milo (dc) Farms

		Acres	Power unit	Man- hours	Machine hours	Machine cost per unit	Acres	Power unit	Man- hours	Machine hours	Machine cost per unit	Acres	Power unit	Man- hours	Machine hours	Machine cost per unit
Size of farm (total acres)																
80																
Item					Dollars		160					320				
										Dollars						Dollars
Crops																
Cotton	35					64					180					
Alfalfa	23					46					96					
Barley (de)	17					40					84					
Milo (de)	17					40					84					
Total	75					150					300					
Operations																
Pick cotton	30	Custom			25.00/ac	180	1-row picker	213	183	10.30/hr	280	1-row picker	400	384	8.05/hr	560
Cotton	34	Custom			6.00/ac	280	Custom			6.00/ac	168	Custom			6.00/ac	
Bale alfalfa	161	Custom			3.50/ac	328	Custom			3.50/ac	672	W-35	58	75	20.00/ac	
Light land preparation	280	W-35		385	280	595	W-35	656	525	6.67/hr	1,044	C-55	145	115	14.55/hr	
Heavy land preparation	46	Custom			6.50/ac	91				6.50/ac	180	C-55	138	113	2.10/hr	
Mow alfalfa	161	W-35		61	50	1.32/hr	322	W-35	121	101	6.96/hr	672	W-35	258	240	434/hr
Bale alfalfa	161	W-35		30	42	2.57/hr	322	W-35	101	85	1.30/hr	672	W-35	210	176	1.27/hr
Cultivate cotton and milo	284	W-35		57	47	1.84/hr	484	W-35	108	89	1.35/hr	888	W-35	207	171	.96/hr
Haul cotton g/	70	Truck		130	400	1.75/hr	128	Truck	237	183	1.35/hr	280	Truck	444	384	3.90/hr
Misc. light operations	347	W-35		94	79	1.60/hr	688	W-35	186	156	1.50/hr	1,344	W-35	363	305	1.35/hr
Total g/				717	578				1,682	1,382				2,634	2,153	
(Labor losses not associated with field operations)				89					217					322		
Power equipment																
35 HP wheel tractor																
35 HP wheel tractor					478	3.65/hr				1,139	3.00/hr		1		1,879	3.00/hr
35 HP crawler tractor															531	5.70/hr
80 HP crawler tractor																
120 HP crawler tractor																
Self-propelled baler																
Self-propelled cotton picker																
(2-row)																
Self-propelled combine																
Self-propelled sweeper																
Automotive equipment g/	60				8.44/ac	160				5.34/ac	320					5.00/ac
Item					640		1,280					2,560				
Crops																
Cotton	212					358					800					
Alfalfa	211					425					944					
Barley (de)	175					357					888					
Milo (de)	175					357					888					
Total	600					1,800					3,000					
Operations																
Pick cotton	428	2-row picker	357	285	18.00/ac	716	2-row picker	597	477	20.00/hr	1,600	2-row picker	1,333	1,067	18.30/hr	
Cotton	350	Custom			6.00/ac	774	SP combine	338	876	10.40/hr	1,976	SP combine	847	706	9.65/hr	
Bale alfalfa	1,477	W-35		304	164	12.80/hr	3,185	SP baler	407	395	11.83/hr	5,484	SP baler	1,384	1,061	11.97/hr
Light land preparation	2,048	C-80		660	588	1.05/hr	1,050	C-80	1,314	425	1.55/hr	2,020	C-120	2,050	1,660	1.55/hr
		W-35		364	307	.65/hr		C-55	1,377	1,086	1.05/hr	1,976	SP combine	1,494	1,195	.98/hr
Heavy land preparation	399	C-50		211	171	2.10/hr	709	C-80	417	319	1.57/hr	1,771	C-120	505	433	2.44/hr
Mow alfalfa	1,477	Sweeper		443	369	4.70/hr	3,185	Sweeper	998	796	4.29/hr	5,484	Sweeper	2,548	2,180	4.10/hr
Bale alfalfa	1,477	W-35		231	204	.76/hr	1,085	W-45	698	413	.72/hr	5,834	W-45	1,382	1,116	.63/hr
Cultivate cotton and milo	1,634	W-25		380	314	.82/hr	2,922	W-25	680	568	1.04/hr	6,776	W-45	1,576	1,303	.81/hr
Haul cotton g/	428	Truck		793	611	.82/hr	716	Truck	1,380	1,023	.75/hr	800	Truck	1,462	1,143	.75/hr
Misc. light operations	2,548	W-35		345	290	1.15/hr	1,838	W-25	1,305	1,097	.92/hr	11,288	W-25	3,116	2,680	1.10/hr
Total g/				4,353	3,583				8,479	6,577				17,898	14,625	
(Labor losses not associated with field operations)				473					1,014					2,506		
Power equipment																
85 HP wheel tractor	1				604	3.00/hr	2			8,078	2.80/hr	4			5,939	2.70/hr
35 HP wheel tractor	1				955	3.05/hr	2					2			1,195	5.35/hr
35 HP crawler tractor										1,086	5.05/hr					
80 HP crawler tractor	1				699	6.85/hr	1			743	6.65/hr	3			3,293	8.20/hr
120 HP crawler tractor															1,061	see bale
Self-propelled baler										393	see bale				1,067	see pick
Self-propelled cotton picker	1				285	see pick cotton	2			477	see pick cotton	3			see bale	see pick
Self-propelled combine										276	see combine	2			706	see combine
Self-propelled sweeper																see combine
Automotive equipment g/	640				369	see 3.72/ac	1			796	see mow	3			2,121	see mow
						3.72/ac	1,280			3.03/ac	3,000				2,434	3.00/ac

2. The second section focuses on the role of communication in project management. It highlights the need for clear, concise, and timely communication between all stakeholders involved in a project. The text provides guidelines for effective communication, such as using appropriate channels and formats, and encourages regular updates and reporting.

3. The third part of the document addresses the challenges of resource allocation and management. It discusses the importance of understanding the available resources and their limitations, and provides strategies for optimizing their use. The text also touches upon the need for flexibility and adaptability in response to changing circumstances.

4. The final section discusses the importance of risk management and contingency planning. It emphasizes the need to identify potential risks early on and develop strategies to mitigate them. The text also discusses the importance of having a contingency plan in place to deal with unexpected events or emergencies.